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SILURIAN DEPOSITS ON THE AK-KERME PENINSULA

by

B. M. Keller

ABSTRACT

A description of the classical Silurian strata of the western Balkash area, developed on the Ak-Kerme peninsula, is given. The discovery of graptolites in Wenlockian and Llandoverian deposits greatly influences the stratigraphic scheme of the peninsula.

* * * * *

1. Introduction

The Ak-Kerme peninsula extends from the west coast of Lake Balkash towards the south. Mynaral is of particular geological interest. The small, low, shining, limestone hills stand out among the monotonous, burnt-out, yellowish-brown hills of the western Balkash area. It is natural that these exposures of limestone, containing a rich fauna of Silurian age, should have attracted investigators. They were first discovered in 1903 by L.S. Berg, who assembled a collection of fossils which was later studied in detail by P.I. Stepanov [3], who established the presence of Silurian fauna. D.I. Yakovlev studied the details of the Ak-Kerme Silurian deposits on which the geological scheme of the peninsula are based. He discovered a rich collection of trilobites and brachiopods in the limestone. The description of the trilobites was incorporated in V.N. Weber's monograph [1]; the brachiopods were studied by O.I. Nikiforova. The results of geological observations and descriptions of the brachiopods are published in another volume [2].

By comparison with other fauna, O.I. Nikiforova established the Wenlockian and Ludlovian ages of the various exposures; their relative position was not established because of the exceptionally complicated structure of the peninsula. The massive reef-like limestones of the Silurian exposures are replaced by sandstone-clay deposits of the same age. These conditions are complicated by the presence of a system of folds and upthrusts.

Further investigations by A.M. Belyayev and A.E. Repkina, who collected valuable (unpublished) data on the stratigraphy and tectonics of the Mynaral district, did not clarify in detail the structure of the Ak-Kerme peninsula.

The Ak-Kerme peninsula was investigated during the period from 1952 to 1955, in conjunction with work in other districts of Kazakhstan. During the investigation, paleontologists and stratigraphers participated and assembled collections of (coral) tabulae (O.P. Kovalevskiy), (coral septa) ridges (V.A. Sytova), and trilobites (M.N. Chugayeva). The study of these fossils, which included brachiopods and graptolites, by the above-mentioned workers and communicated by T.B. Rukavishnikova and A.M. Obut, considerably facilitated the determination of the age of the individual blocks. The coral tabulae especially were closely studied; their description is incorporated in O.P. Kovalevskiy's thesis (1955). Nevertheless, the stratigraphy is not clear in many respects and only subsequent to our work has elucidation of the detailed stratigraphy of the area become possible. The results obtained from an approximate diagram of the peninsula, may help to clarify the stratigraphic relationships.

The following collectors took part in the field work: N.B. Keller, A.I. Polozhikhina, S.B. Prokopenko, V.R. Tkachev, G.R. Shishkina; their unrelenting activity contributed considerably to the completion of the work.

2. Stratigraphy

Ordovician System

As far as is known, the oldest deposits in the Ak-Kerme peninsula are the Ordovician deposits shown at two points (see fig. 1). One exposure is on the narrow isthmus in the eastern part of the peninsula. Silurian rocks outcrop from this area to the boundary limiting the limestone on the west.

The section is:

1) Yellow-grey flinty shales with impressions of Climactograptus sp., Glyptograptus sp. (point 15). On the south coast of the peninsula, approximately level with this block, basic crystalline effusives 140 m thick outcrop.

2) Dense polymict, feldspar sandstone, in thick layers at depth and thin layers toward the top are interbedded with siltstones of grey or reddish color. The sandstones form a ridge in relief. The thickness is 50 m.

3) After a considerable gap (corresponding to the narrowest part of the isthmus), covered by contemporary sand from Lake Balkash derived from folds of Silurian limestone, are found friable, light-colored, calcareous sandstones and, higher up, yellowish and reddish-brown siltstones, with Dicellograptus sp., Glyptograptus sp. and other graptolites (point 13). Thickness 110 m.

The second point of exposure of Ordovician rocks is on the north coast of the Ak-Kerme peninsula, at the point where it joins the mainland. Here, in the center of an anticlinal fold, a bed with greenish-grey seams of calcareous sandstone, silicified yellowish marl and higher up, reddish shale, marl and sandstone is exposed. In the dark-grey, nearly-black shaly clay in this bed, thick Dicellograptus and Rectograptus sp. were found (points 4 and 5). The presence of the former confirms the Ordovician age of the surrounding deposits.

The lithologic composition of the Ordovician rocks of the eastern part of the Ak-Kerme peninsula is nearly identical with that of the Silurian deposits developed in the same district.

In particular, the sandstone of bed 2 of the adjoining section (point 14), characterized petrographically by interlayering with siltstones and by its thickness, corresponds exactly to the standstone of point 8, which is covered with red siltstones. However, Ordovician Dicellograptus were found at point 13 and Silurian Monograptus and Pristiograptus at point 8. Thus, it may be assumed that Dicellograptus is sometimes present in the Llandoverian Silurian series. This hypothesis, however, is still unconfirmed.

Silurian System

The Silurian deposits in the Ak-Kerme peninsula underwent complicated facies changes. Multi-colored, sandy argillaceous deposits of short duration are replaced by massive, reef-like limestones. The thickness of the rock changes acutely. The relationship between these two facies, outlined generally by A.M. Belyayev, are now better understood since the discovery in the terrigenous Llandoverian, Tarannonian and Wenlockian rocks of numerous graptolites, by which the age has been accurately established.

Llandoverian-Tarannonian

One of the best sections of Llandoverian and Tarannonian deposits is found along the north coast of the peninsula (point 8). Here the following succession is observed (fig. 2):

S^{II} 1. Dense conglomerates with greenish-grey sandy cement covered by a rubble of pink granite, pink and grey limestones, green tuffs and dark quartzite, the visible thickness is 15 m.

S^{II} 2. Dense, greenish-grey sandstone, interbedded with siltstones (basaltic blocks); thickness of the interbedded sandstone 0.05 - 0.8 m, siltstones 0.08-0.10 m. In the block (1.7 m) of dense, finely striated siltstones with sparse sandstone intersections, Monograptus sp. and Pristiograptus sp. were found: general thickness of the sandy block 42 m.

S^{T-W} 3. Dense chocolate-brown and reddish-brown, conchoidal siltstones with sparse, thin, interbedded sandstone; thickness 50 m.

S^{W-I} 4. Dense reddish-brown conglomerates with clay cement and pebbles of quartzites and siltstones, occasionally massive; thickness 1.5 m.

S^{W-I} 5. Dense, shining and reddish-brown Akkansian limestone; thickness over 100 m.

The section shown evidently has insufficient paleontological characteristics, but the blocks formed in it can be easily traced in other areas of the peninsula. Thus, the red siltstones of the 3rd layer are exposed in the area of points 6 and 7, where they contain the characteristic Monoclimacis sp. and Monograptus ex gr. priodon Bronn. It is strange that farther west, at point 5, the red argillites directly overlie the rocks at

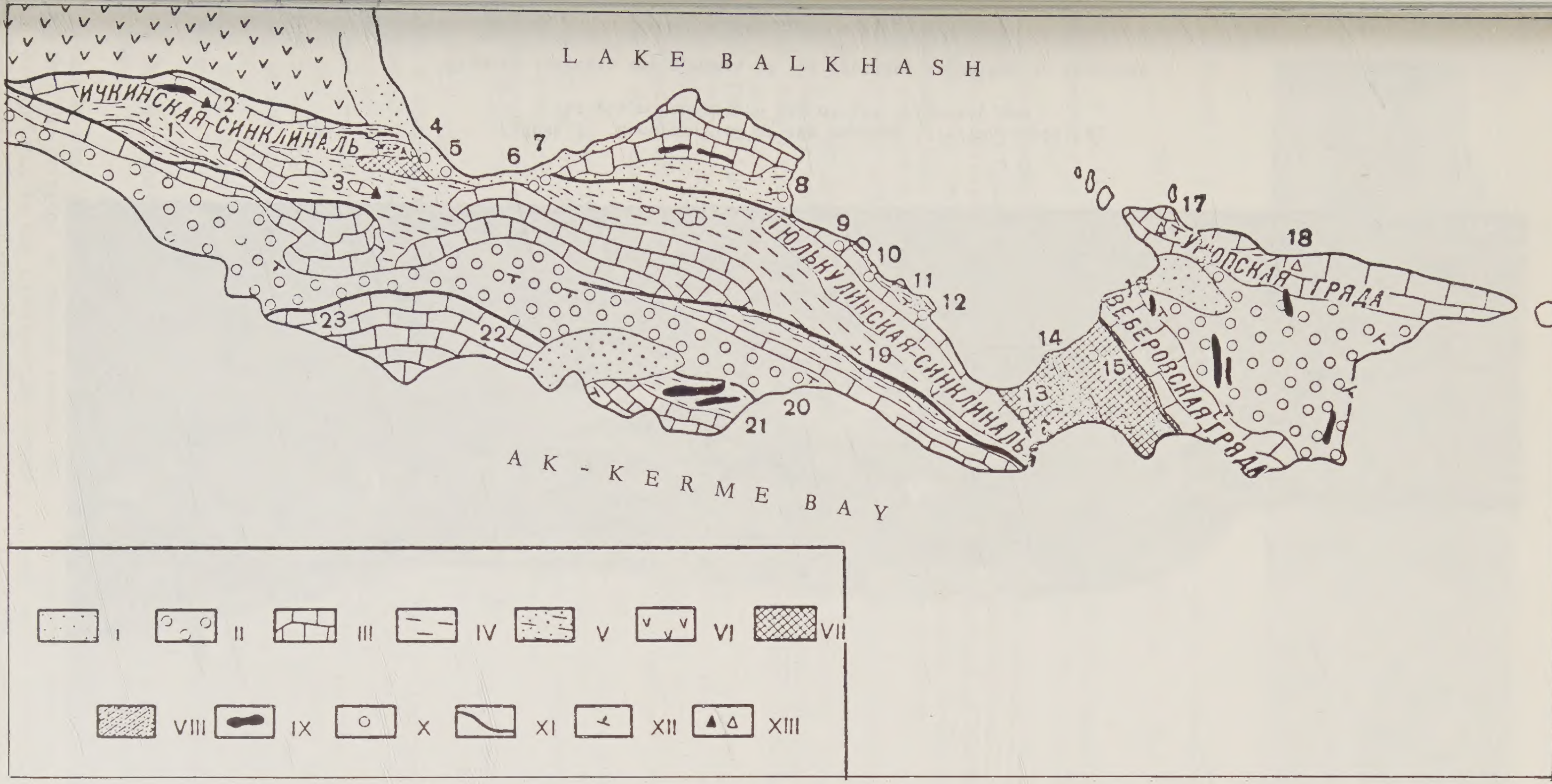

FIGURE 1. Geological sketch of the Ak-Kerme peninsula.

I - Quaternary deposits; II - Devonian conglomerates, sandstone and red argillites; III - Akkansic limestone of Ludlovian and Wenlockian ages includes Llandoverian in the Ichkinsky syncline; IV - Wenlockian bed -- multicolored argillites with interlayers of sandstone and lenses of limestone; V - Tarannonian multicolored argillites and sandstone; VI - Silurian and later effusives; VII - Ordovician silicified shale, argillites; VIII - Ordovician sandy deposit between shale; IX - Diabase dike; X - Occurrence of graptolites; XI - Occurrence of tabulae; black in Llandoverian Tarannonian; light in Ludlovian; XII - Faults; XIII - Dips.

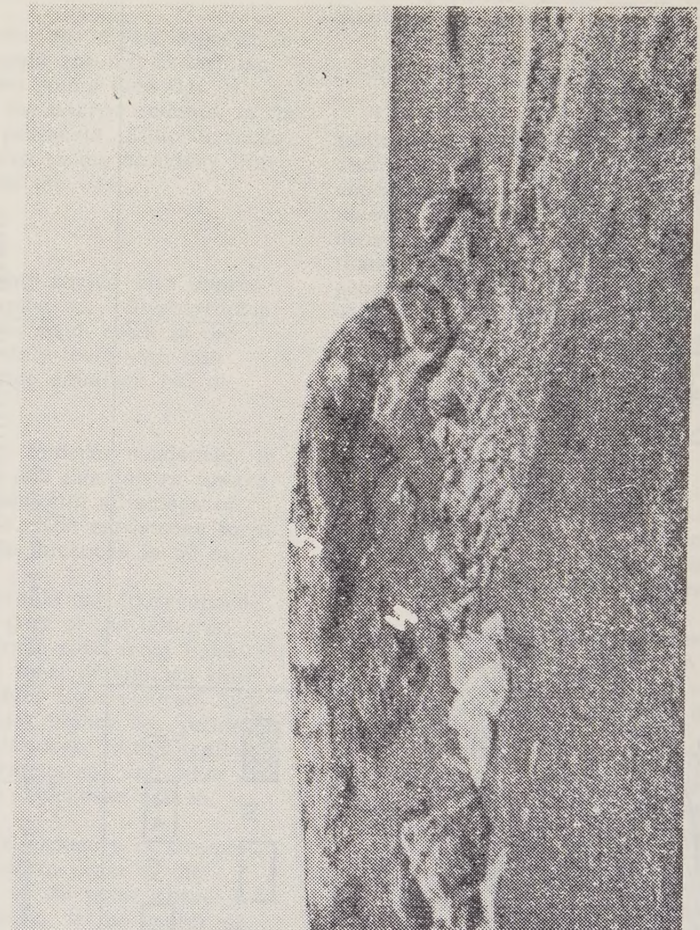

FIGURE 2. General view of the exposed Silurian deposits at the northeastern end of the Uryupskiy bed.

Figures indicate the numbers of the sections described in the text.

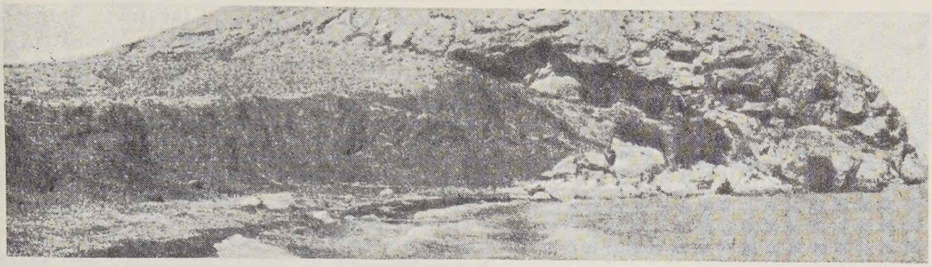

FIGURE 3. Exposed Silurian beds on the Northern coast of Ak-Kerme peninsula (point 8).
Left: schist no. 3, right: Akkansic limestone no. 5. View to northwest.

he top of the Ordovician and do not contain :onglomerates or basaltic sandstones.

To the southeast, a limestone bed which xtends from the coast of Lake Balkhash bviously corresponds to the Tyulkulinsky ynclinal fold. On its northeast flank (fig. 3) 'arannonian beds are observed, one of them ccurs at point 9, opposite a cliff which ex- ends far into Lake Balkhash (dip 210° /60°).

S^{II} 1. Light grey and purple siltstones vith irregular lentiform intersections of ense, bright grey limestone; thickness 5-10 m. The layers dip east-southeast (dip 103° 80°). The Tabulata: Mesofavosites ordinatus ov., Propora conferta M.E.M., P. conferta ar. cubiformis Kov. form a complex in the mestone which is related by O.P. Kovalov- kiy to the Llandoverian; thickness 6.5 m.

S^{T} 2. Dense, bedded siliceous argillites p to 10 cm. thick, sometimes finely pli- ated, with Retiolites geinitzianus Barr., pirograptus spiralis (Geinitz) S. sp.; thick- ess 1.5 m.

$S^{W?}$ 3. The reddish layers of siltstones ollow a small zone of distortion and are itersected with calcareous sandstone; thick- ess up to 0.5 m. The sandstone strata are iclined towards the southwest (dip 210° 50°) and they appear to be higher than ayer 2, but the rhythmical character of the andy strata points rather to a displaced ed. It can only be located provisionally bove layer 2; thickness of the entire block 85 m.

4) Dense, light-colored limestone forming ie base.

It can be seen from the illustrated sec- ons that the complex of tabulae related by .P. Kovalevskiy to the Llandoverian forma- on lies below the paleontologically distinct Tarannonian deposits, but is so closely related that it can be regarded as a whole.

The nearest stratigraphic section was established more to the southeast on the same flank of the fold where the following succession of deposits, dipping 210° /80°, were observed:

S^{II} 1. Alternating, grey, calcareous silt- stones, marl and uneven layers of lentiform grey limestone. Ridges and tabulae occur, Wormsipora hirsuta Lindstrom is present in the tabulae; thickness 15 m.

S^{T} 2. Finely plicated, slightly silicified dark-grey and yellowish-grey siltstones with Retiolites angustidens, Elles et Wood, Mono- graptus pandus Lapworth; thickness 15 m.

S^{W} 3. Coarse-grained and medium- grained sandstone, thick calcareous layers with sparse trilobites and brachiopods; thick- ness 4 m.

S^{W} 4. Limestone forms a wide bed par- allel to the coast of Lake Balkhash.

This bed changes strike quite sharply; at a distance of 400 m (point 10) layer 2 can be clearly traced to the northeast; directly above lies the clayey block (10 m), but con- siderably younger graptolites are present in its upper part. Among them A.M. Obut identified Monograptus priodon Bronn., Cyrtograptus murchisoni Carr, C. sp. This complex of species is characteristic of the lower zone of the Wenlockian formation.

The block of Tarannonian slate varies somewhat in thickness and sometimes com- pletely disappears. Thus, in the limestone belt extending from point 2 to 4, a block of limestone containing abundant tabulae lies next to the Ordovician rocks, with Paleo- favosites alveolaris Goldf., P. Simplex

Tschern., Mesofavosites multitabulatus Bukhin and other species forming a complex related by O.P. Kovalevskiy to the Llandoverian formation. This limestone penetrates the calcareous layer, which is mainly composed of Wenlockian-Ludlovian limestone.

Wenlockian Formation

The deposits of the Wenlockian formation on the Ak-Kerme peninsula are represented by two facies -- the folded terrigenous red beds of sandstone and siltstone, and the calcareous facies.

As noted above, on the northeast flank of the Tyulkulinsky syncline, the tops of the terrigenous material underlying the limestone contain the graptolites characteristic of the lower Wenlockian formation. Above the layers with Tarannonian graptolites, are thin red deposits. On the other flank these are considerably thicker.

Between them stretches a dense, brownish-grey sandstone (point 19), with seams of limestone containing Karpinskya Nalivkini Nikif., Plectatrypa ex gr. marginalis Dalm., Conchidium tenuicosta (H. et. W.), Rhynchotreta cf. cuneata (Dalm., R. sp. (identified by T.B. Rukavishnikova).

More solid and complete layers of the same rocks can be observed along the south flank of the Ichkinsky syncline (point 1), where the following strata (dips 15-20^{o} /40-50^{o}) are recorded:

$S^{II?}$ 1. Dense grey sandstone 30-40 cm. thick alternating with slate. The deposit is characterized by moderate rhythm; total thickness 12 m.

S^{W} 2. Coarse sandstone with pebbles and grains of limestone. Conchidium biloculare L., Spirifer jakovlevi Nikif., Delthyris sp. (identified by O.M. Nikoforova); thickness 11 m.

S^{W} 3. Red slate with thin layers of sandstone; thickness 10 m.

S^{W} 5. Ill-defined layers of pink limestone with Conchidium tenuicosta H. et W., Dolerothis cf. rustica Sow., Karpinskya nalivkini Nikif., Atrypa cf. granulifera Barr., Pentamerus sp., etc. (identified by T.B. Rukavishnikova, 1955). Conchidium boloculare L., Lissatrypa linguata Buch., (identified by O.I. Nikifirova, 1955); thickness 15 m.

S^{W} 6. Small-grained conglomerates with pebbles of veined quartz, siliceous rocks and sandstone; thickness 10 m.

S^{I} 7. Ill-defined layers of dense, bright limestone, sandy towards the bottom, with brachiopods, Conchidium biloculare L., C. tenuicostata (?) Hall., Lissatrypa linguata Buch., Atrypa reticularis L. (identified by T.B. Rukavishnikova, 1955). In the latter's catalogue, according to the collection of V.A. Sytova (1953), Conchidium sp., C. knighti Sow.*(1004/1), appears. The limestone of layer 7 forms a stratum clearly visible in relief. Visible thickness is appr imately 30 m.

Thus, as in the Tyulkulinsky and Ichkins synclines, a marked disparity is observed on the flanks. As mentioned above, slate a limestone occur on the northeast flank and are characterized by the complex of Llando verian tabulae and by Tarrannonian graptolites. On the southwest, red rocks with minor intercalations of sandstone and limestone occur, characterized by the Wenlocki brachiopod complex. The presence of Wenlockian forms in the massive limestone facies characterized by brachiopods was established previously by O.I. Nikiforova who lists 8 species in the limestone of the south coast of the peninsula from point 13 (coinciding with point 23 of the diagram), including Orthis (Dolerorthis) rustica Sow., Conchidium tenuicosta H. et W., Rhynchotr cuneata Dalm., Karpinskya nalivkini Nikif. Spirifer jakovlevi Nikif., etc. The trilobi Acrolichas sp. was found in the same laye O.I. Nikiforova indicates that in this complex relatively ancient forms (marked *) as well as Devonian forms are present. As th whole, the association indicated characterizes the middle Silurian.

Ludlovian Formation - Akkansian limestone

Ludlovian deposits on the peninsula consist mostly of limestone and merge into th Akkansic range, the lower part of which is related to the Wenlockian. One of the best Akkansian sections is visible in the extrem eastern (Uryupsk) series within the limits the peninsula, where this succession of roc was established (point 17, fig. 4):

S^{W} 1. Dense grey massive limestone wit Pentamerus oblongiformis Nikif., Delthyris aff. Pentameriformis Tschern., Dolerorthis aff. rustica Sow. The thickness is 15 m.

S^{I} 2. Calcareous conglomerate with polished sandstone, pebbles of veined quartz, green tuffs; the thickness is 60 m.

S^{I} 3. Dense red limestone, forming lenses, the thickness changes rapidly from 0.5 to 4 m.

S^{I} 4. Thin-layered limestone with

embedded lenses, alternating with yellowish argillaceous limestone and marl, filled with solitary corals; thickness 2.5 m.

S^I 5. Dense massive grey and pink limestone Conchidium cf. knighti sow., C. sp., Atrypa cf. Granulifera Barr., thickness approx. 60 m.

This limestone is overlain by conglomerates which are probably Devonian. Among the tabulae collected by O.P. Kovalevskiy, are Multisolenia tortuosa Fritz., Favosites stepanovi Kov., F. rectus Kov., F. syringolitoides Kov., Halysites opimus Kov., H. bifidus Kov., H. bellus Kov. and other forms, which, according to the above-mentioned worker, form complexes characteristic of the lower Ludlovian.

FIGURE 4. Exposed Silurian deposits along the northeastern coast of Ak-Kerme peninsula (Pt.9). 1-Llandoverian deposits; no.1; 2-Tarannonian slate with graptolites, no. 2; 3-red siltstone and sandstone, no. 3; 4-limestone, no. 4.

The pink massive limestone differs somewhat in facies, and contains large segments of crinoids, forming the more westerly Weber layer. Under this layer lie calcareous sandstones and argillites with Pristiograptus sp. The rich collections of brachiopods and trilobites related to D.I. Yakovlev's point 722 [2], originate from a higher limestone. In our collection of brachiopods from the above mentioned deposit, T.B. Rukavishnikova identified Lissatrypa linguata Bouch., Atrypa ex gr. marginalis Dalm., Conchidium cf. tenuiscosta H. et W., C. cf. striatus Eichw., Spirifer (Eospirifer) cf. lalchaschensis Nikif. and other species, constituting the complex characteristic of the Ludlovian formation. O.I. Nikiforova listed 12 species in the Weber bed and considers the age of the enclosed deposits to be upper Ludlovian. V.N. Weber admits that the investigated limestone belongs to deeper layers of the Ludlovian formation. M.N. Chugayeva arrived at the same conclusion after finding tail segments of Remopleurodes sp. in a new collection of trilobites, in addition to the species described by V.N. Weber. Remopleurodes sp. is generally absent in such recent deposits.

One of the most essential problems of the stratigraphy of the Ak-Kerme peninsula is the conformity between the Uryupskiy and Weber deposits. The rocks of both dip to the southwest, from which it could be concluded that the Uryupskiy is the older and the Weber more recent.

Study of the brachiopods leads to the same conclusion; the complex in the Uryupskiy bed is characterized by similarity with the Konkhidievyye section of middle Ludlovian age. The Weber, on the other hand, is related to the upper Ludlovian deposits. However, such correlation cannot be completely proved. The area between the two deposits is filled with conglomerates of Devonian appearance, with pebbles of reddish-brown quartz porphyry; consequently it is impossible to explain the conformity of the beds on this site. With regard to the ancient appearance of the trilobites in the Weber series and the discovery of extremely ancient graptolites at its base, the hypothesis that the two beds are of the same age cannot be accepted.

Silurian formations and facies types

Two facies are distinguished in Silurian rocks: the calcareous and sandy-clay facies constitute one formation.

The calcareous facies is represented by typical bioherm limestone of massive structure either without bedding or preserving the elements of ill-defined, coarse stratification.

In the marginal parts of the massif the limestone grades into thick breccia, composed of irregular accumulations of angular particles joined by calcareous cement. The limestone massif corresponds, as a rule, to the central parts of synclines. The thinning-out of such a massif can be explained in many cases by elevation of the fold axis. However, direct transition from limestone to a red, sand-slate facies frequently can be observed quite distinctly. Such transitions may be assumed to have taken place on the extension of the calcareous zone to the south from point 5, for example. Naturally, here as well as in other cases, the direct contact of limestone and sand-clay rocks is clearly tectonic and is accompanied by localized contortion along the edge of the two beds, which react completely differently to tectonic pressure.

Sand-clay facies. The special peculiarity of this facies is the rapid change of thicknesses and lithologic composition, especially in transverse extensions of folded structures.

The marked contrast of red sand-clay rocks on the flanks of the Ichkinsky and Tyukulinsky synclines is a good example of this phenomenon. In the Wenlockian formation, the replacement of the nearly 50 m thick southern flank by the 5 to 10 m thick northern deposit can be clearly seen.

The two facies constitute the Balkhash fo formation of bioherm limestone. The formation is distinguished by the close interconnection of rocks of two facies types, by comparatively small thickness of deposits (not more than a few hundred meters) and by a limited platform-like extension. It has probably formed within the comparatively elevated Akkerman anticlinal zone and consists only of shallow beach deposits.

Volcanic formations probably correspond more to the folded areas of the Akkerman zone. A number of porphyrites and tuffs with coarse lenses of acid effusives stretch in a belt along the monoclinal Mynaral block; within the examined area the exposure of this formation can be seen directly to the north of the Ichkinsky syncline. The age of the effusives is confirmed by the discovery in the slaty blocks between the porphyrites of characteristic Tarannonian graptolites (Retiolites geinitzianus Barr gr., etc.). Thus, the volcanics correspond approximately in age to the red argillites of the Ak-Kerme peninsula. The presence of siliceous layers can be related to the influx of surplus silicic acid into the maritime reservoir during volcanic eruptions.

The structure of the Silurian deposits on the Ak-Kerme peninsula indicates that despite the exceptionally complicated correlations of facies and thickness, and despite the presence of folds and faults, it is possible to attribute to one of the underlying Silurian beds the distribution of the outstanding groups of fossil organisms -- graptolites, brachiopods and corals. Especially clear data on the reciprocal correlation of these groups of fossil organisms can be obtained for deposits of Llandoverian, Tarannonian and the lowest Wenlockian. In the upper Wenlockian and in the Ludlovian formation, the graptolites are absent, but the simultaneous discovery of brachiopods and corals also supplies substantial data regarding their vertical distribution.

The first data obtained by O.P. Kovalevskiy (1956) on the vertical distribution of tabulae in the strata of the Ak-Kerme peninsula were of great interest. He distinguished two complexes of species in the limestone facies -- Llandoverian and lower Ludloverian. That these complexes characterize the larger sections of the stratigraphic range of Silurians and include collections from Tarannonian and Wenlockian deposits cannot, however, be disregarded. The discovery of various tabulae complexes representing fractional stratigraphic subdivisions in the Silurian deposits of the western Balkhash area is left to the future.

Equally interesting data may be obtained in the Ak-Kerme peninsula on the vertical distribution of brachiopods in the Silurian deposits among which, as the work of O.I. Nikiforova indicated, many original local species are present. The characteristics of the brachiopod members of Llandoverian, Tarannonian and lower Wenlockian with reference to deposits whose age has been established by the presence of graptolites, would be of great interest.

This study represents preparation for future and more detailed stratigraphic investigations.

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Geological Institute
Academy of Sciences U. S. S. R.,
Moscow

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ON THE HISTORY OF THE RUSSIAN PLATFORM DURING THE TOURNAISIAN AND EARLY VISEAN

by

S. V. Semikhatova

ABSTRACT

The facies and stratigraphic divisions of a Lower Carboniferous formation which forms a narrow zone of thick sediments in the Tatar Republic, the Kuybyshev area and Udmurtia are described. The author distinguishes a zone containing Productus sublaevis Kon. and sandstone formations containing spores which are older than those of the Stalinogorsk horizon. Paleontologic and geologic arguments are given for placing the boundary between the Tournaisian and Visean stages in the Volga-Ural region at the bottom of the zone containing Productus sublaevis.

* * * * *

THE BOUNDARY BETWEEN THE DEVONIAN AND THE CARBONIFEROUS

One of the most difficult problems of Paleozoic stratigraphy, both in the literature of geology and in practice in the Soviet Union, is the location of the beginning of the Tournaisian stage on the Russian Platform -- in other words, the question of where to fix the boundary between the Devonian and the Carboniferous. This question, which was brought up by P. Struve in 1886 and K. Lisitsyn in 1908, has been answered differently by different investigators. In the presently accepted unified correlation of Carboniferous stratigraphy [17] this boundary is drawn along the contact between the bed that contains Astarte socialis and Serpula vipera and the bisphaeral limestones of the Malevian horizon. In resolutions by the Committee for Establishing a Unified Scheme in 1951, the boundary thus established was characterized as conditional and subject to further study of the fauna. Many researchers are now in favor of lowering the boundary. One of the strongest arguments for doing this is that the turning point in the movements of the earth's crust that started a new cycle in the geologic history of the Russian Platform occurred not in the Malevian age but somewhat earlier.

Evidence that upward movements of the crust changed to subsidence at the end of the Famennian age is found, according to some authors, in the Moscow syneclise at the base of the Khovanian beds [31, 32, 33]. For this reason many are in favor of placing the Carboniferous-Devonian boundary at the base of the Khovanian beds. For similar reasons investigators working in the eastern parts of the Russian Platform suggest fixing the boundary at the base of the beds containing Endothyra communis Raus., which lie under the Malevian horizon in the Volga-Ural region. Until recently these beds have correlated, and by many workers are still correlated, with the Ozersko-Khovanian strata in the vicinity of Moscow. Recently they have been correlated with the Khovanian beds. What is the evidence supporting these mutually contradictory correlations?

It is well known that the Khovanian beds in typical stratigraphic sections contain few organic remains. There is no mention of Foraminifera in the literature. Recent papers by V.M. Pozner and by V.A. Nazarova have added to the fauna of these beds in the southern limb of the Moscow syneclise by discovering the following ostracods: Sulcella multicostata Posn., Healdianella punctata Posn., Bairdiacypris lutea Posn., Lichwinella (?) chovanencia Posn., Glyptolichwinella spiralis (Jon. et Kirk.), and Astarte (Eridoconcha) socialis (Eichw.).

S.G. Rakhmanova [16], using the word "spheres," has described some organic remains in the Khovanian beds whose position in the system is not clear and which

had been mentioned earlier by M.S. Shvetsov as plant remains [31]. In the southwestern quarter of Sheet 58 of the Geologic Map, A.P. Ivanov and Ye. A. Ivanov [7] mention the following brachiopods in the Astarte socialis beds, which are generally poor in fauna: Plicatifera fallax Pand., Camarotoechia panderi Sem. et Moell., Chonetes nana Vern., Athyris puschiana Vern., Streptorhynchus cf. umbraculum Schl., and Spiriferina cf. octoplicata Sow.[1]

This evidence, unfortunately, is insufficient for a correlation of the Khovanian beds near Moscow with the Endothyra communis beds in the eastern part of the Russian Platform. No "little spheres" have been found in the Endothyra communis beds, and the ostracods have scarcely been studied; according to O.A. Lipin, D.M. Rauzer-Chernousova and Ye. A. Reytlinger, some of the brachiopods listed above are found in the Endothyra communis beds (Plicatifera fallax, Camarotoechia panderi, Athyris puschiana), but these organisms, both in the vicinity of Moscow and in the Volga area, also occur in the sediments of the Likhvinian substage, and thus cannot be used as criteria for an exact correlation of the beds that contain them. The Endothyra communis beds are rich in Foraminifera which have been thoroughly studied, but these, as has been said above, do not occur in the Khovanian beds in the area where they are typically developed.

Certain authors consider L.M. Birina's remarks [5] on the occurrence of Astarte socialis with Endothyra communis near Syzran' as evidence for regarding the deposits under consideration as being of the same age. But this one fact alone, which applies not to an assemblage of fauna but to only a single species, is clearly not sufficient evidence for considering the two sets of beds to be of the same age. The fact that Astarte socialis has been found with Endothyra ex gr. communis and bisphaeral brachiopods in zone C^t_1 of the Carboniferous of the Donets area [3] is also insufficient grounds for identification of the Khovanian beds near Moscow with the Endothyra communis beds. It is still an open question whether Astarte socialis existed earlier or whether organisms of the Endothyra communis group appeared earlier here than in the type localities of the deposits in question. In general, however, at the present level of knowledge a correlation cannot be based on the presence or absence of one or two species.

[1] There is no mention of these organisms in the Khovanian beds in the "Guide to the Paleozoic Brachiopods of the Moscow Basin" in the index to the vertical distribution of these forms.

At Arched (in the Stalingrad Oblast') a typical assemblage of ostracods has been found in the Khovanian beds [12, 26]. The Foraminifera are represented here only by Umbella sp., Nanicella cf. lugeni N. Tschern., and Bisphaera aff. elegans Viss. The underlying deposits are assigned, on the basis of the ostracods in them, to the Dankovo-Lebedyan beds. Endothyra communis Raus., Septatournayella rauserae Lip. and a few others [26] occur in them at a depth of about 50 meters below the base of the deposits containing the Khovanian ostracods. S. rauserae, it is known, occurs typically in the lower half of the Endothyra communis beds. But the lack of typical Foraminifera in the Khovanian ostracod strata (which is probably due to peculiarities of the sedimentary environment in these strata) makes it impossible to determine the relationship of the complexes of beds under consideration in this stratigraphic section.

Thus great caution is necessary when identifying End. communis beds as being synchronous with any part of the stratigraphic section of the beds at the boundary between the Devonian and the Carboniferous on the right bank of the Volga or in the Moscow area, at the present level of knowledge.

If this is true of the overall identification of the End. communis beds with Khovanian deposits, it is even less possible to assume that the lower boundaries of these beds are definitely the same: there is no evidence that the two boundaries are of the same age. There is evidence, to be sure, that fluctuations in the process of deposition (which are seen at the base of the Khovanian beds near Moscow in indications of transgressive deposition, and at the base of the End. communis beds in the Volga area in the change from a primarily dolomitic sequence to normal marine limestones) are in the same direction in both beds; but these indications might have and probably did appear, at different times in the peripheral areas of the sedimentary basin and in its interior areas to the east. The relative ages of the bases of the two sets of beds must be established by paleontological evidence.

Thus it is still appropriate to adhere to the boundary between the Devonian and the Carboniferous that was adopted in the Unified Scheme in 1951. In the meantime a study must be made of the fauna, and particularly the ostracods of the Khovanian beds and the End. communis beds, in order to obtain strict evidence for an accurate correlation and determination of stratigraphic boundaries.

The Likhvinian age. Transgressions in the Khovanian, Malevian and Upinian ages

TABLE 1. Faunal assemblies of the Likhvinian substage in the Moscow basin [19].

Malevian horizon	Upinian horizon
Schuchertella planiuscula Sem. et Moell.	Schizophoria upensis Sar.
Rugosochonetes malevkensis Sok.	Schuchertella semenovi Sok.
Plicatifera fallax (Pand.)	Rugosochonetes upensis Sok.
Concrinella panderi Auerb.	Plicatifera kalmiusi (Liss.)
Camarotoechia panderi Sem. et Moell.	Pl. ivanovi Sok.
Eomartiniopsis helenae Sok.	Cancrinella panderi Auerb.
Ambocoelia urei (Flem.)	Waagenococha krapivnensis Sok.
Punctospirifer multicostatus Sok.	Camarotoechia upensis Sok.
P. malevkensis Sok.	C. ivanovi Sok.
Hustedia tulensis (Pand.)	Paulonia media Leb.
Athyric puschiana Vern.	P. ranovensis Peetz.
Ath. vogdti Peetz.	Gurichela upensis Sok.
Ath. pectinata Sem. et Moell	Eomartiniopsis elongata Sok.
Ath. hirsuta Hall.	Ambocoelia urei (Flem.)
	Hustedia tulensis (Pand.)
	Athyris puschiana (Vern.)
	Ath. vogdti Peetz.
	Ath. subpyriformis Sem. et Moell.
	Ath. pectinata Sem. et Moell.
	Ath. hirsuta Hall.

followed each other in direct succession, with a few fluctuations in the depositional environment at the beginning and end; the evidence for these fluctuations is traces of small, local erosional intervals at the top of the Khovanian beds [5], in the transgressive deposition of Upinian sediments at the edges of the Moscow basin [24], in deposits of the C^t_1 b zone on the Voronezh massif [29] and others.

On the Russian Platform and the adjacent regions these transgressions moved westward, from the Urals and the western Ural foothills toward the western portions of the Moscow basin and from the eastern regions to the Donets basin and its western extension [1].

The history of the Tournaisian seas on the Russian Platform might be clarified by examining the stages in the development of the fauna that inhabited these seas; this article will examine the changing assemblages of brachiopods.

In Khovanian times there were evidently few brachiopods in the basin. One unfavorable factor preventing their spread was, possibly, an increased concentration of salts eroded from the Ozersk series [31, 32], which lay directly beneath the Khovanian basin and formed its shores.

The brachiopods that inhabited the Malevian sea in the Moscow basin were of numerous types and usually small: such an assemblage is generally associated with unfavorable conditions. It is possible that there was a continuation of high salinity in this area, but a stronger factor was probably the difficulty of migration, since most of the brachiopods of the Malevian horizon belong to genera that are absent in the Famennian stage of the Moscow basin (Cancrinella, Plicatifera, Punctospirifer, Hustedia). This fauna had evidently migrated from some remote refuge where conditions favored its development at the end of the Famennian and beginning of the Tournaisian ages [21].

In the Upinian horizon the brachiopods of the Moscow basin begin to show more variety than in the Malevian; a number of genera appear which are not found in Malevian deposits: Schizophoria, Waagenoconcha, Paulonia, Guerichella.

The greater variety of the fauna indicates that there was freer access to the parts of the basin from which the fauna migrated. This was most probably due to an increase in the overall depth of the sea, as compared to the Malevian sea. The occurrence of representatives of genera that were absent in the Malevian fauna of the Moscow basin testifies that the Upinian fauna in this region had, to a considerable degree, originated elsewhere.

The question as to whether the fauna of

the Likhvinian substage in the Moscow basin area originated in the western European Tournaisian basin must be answered in the negative. The list in Table 1 above shows an almost complete absence of forms that were common to the fauna of the Tournaisian stage in western Europe. The brachiopods of the Likhvinian substage are unknown in the lower Carboniferous of western Europe; in fact, they are not even close relatives. In this assemblage, which consists of eastern European types, there is an unexpected occurrence of two species -- Ambocoelia urei and Athyris hirsuta -- of which the former is found in England and Belgium and the latter in the Carboniferous of North America. Their presence in the list is most likely due to the convergent development of certain factors.

There is also an almost complete absence of Siberian, Kazakhstan and Central Asian fauna among the brachiopods of the Likhvinian substage in the Moscow basin; there is only one common form, for example -- Camarotoechia panderi -- from the Kassinian beds of northeastern Kazakhstan.

The brachiopods in the Kassinian beds of Kazakhstan include a number of species that are also typical of the Kinderhookian stage in North America, in addition to certain western European species or species close to them [13].

Thus, to judge by the brachiopods, the lower Tournaisian basin in northeastern Kazakhstan communicated with both the western European and the North American seas, and there was a considerable intermigration of fauna. The Moscow basin, on the other hand, evidently did not participate in this exchange of fauna.

The basins that covered the Volga-Ural region and the Dnepr-Donets depression also did not take part in the exchange of fauna with western Europe and North America; in the Likhvinian sediments of both these basins there is a predominance of the same suite of brachiopods as in the Moscow basin. In the Malevian strata at Baytugan and Krasnaya Polyana there are occurrences of Schizophoria upensis Sok., Rugosochonetes malevkensis Sok., Ambocoelia urei Flem., Paulonia close to P. media Leb., Eomartiniopsis elongata Sok., Camarotoechia ivanovi Sok., Guerichella upensis Sok., Athyris pectinata Sem. et Moell., Athyris cf. puschiana Vern. (according to O.A. Lipina, D.M. Rauzer-Chernousova and Ye. A. Reytlinger; identifications by A.N. Sokol'skaya).

The species which are found in the Likhvinian fauna of the Moscow basin are mentioned by the same authors as occurring in the Volga-Ural region and the Endothyra communis deposits (Camarotoechia panderi, Plicatifera fallax, Athyris puschiana, Athyris pectinata, and Paulonia ranovensis).

Thus the Volga-Ural region, the End. communis beds and the Malevian strata contain species which are widespread in the Moscow basin only in Upinian times. The Malevian strata in the Dnepr-Donets basin, as in the Volga-Ural region, show a development of organisms which entered the Moscow basin only in Upinian time [25]. Certain forms appear in the brachiopod assemblage of the Donets basin earlier than that of the Moscow area. Here zone C^t_1 a, which is correlated [2] with the Ozersk-Khovanian and the bisphaeral beds, contains: Cancrinella panderi (Auerb.), Productella kalmiusi Liss., Chonetes hardrensiformis Rot., Camarotoechia domgeri Tschern., Camarotoechia panderi Peetz., Cam. kalmiusi Rot. (ex gr. livonica Buch.), Martiniopsis waschcuricus Frcks., Paulonia ranovensis Peetz., Pr. kalmiusi and P. ranovensis, which are known in the Upinian strata of the Moscow area, whereas Cancrinella panderi and Camarotoechia panderi are in the Malevian beds.

Thus the areas under consideration were inhabited in Likhvinian time by similar assemblages of brachiopods, and there was a migration of many species from the south and east into the Moscow area; all of these suites were typically isolated from the brachiopods of the same age in western Europe, the region east of the Urals and North America.

The Chernyshinian age. At the end of Likhvinian and the beginning of Chernyshinian times the subsidence of the Russian Platform, which had begun at the end of the Devonian, changed within a short interval to uplifts which were evidently more rapid in the areas that fed terrigenous sediments into the sea on the Russian Platform. These uplifts are evidenced by the formation of the Ageyev series, which lies at the base of the Chernyshinian substage. This series, or those analogous to it, spread over a great area. It is well developed in the southern part of the Moscow syneclise; it has an analogue in the Dnepr-Donets basin [4, 25]; and some of the terrigenous rocks making up the lower part of the Chernyshinian substage also occur in the Stalingrad area of the Volga River [12, 22, 26]. Apparently not only the western and northwestern shores of the Moscow marine basin but also the Ukrainian massif of crystalline rocks and the Voronezh massif were subjected to tectonic uplifts at this time. The approach of the shoreline is also shown in the appearance of carbonaceous plant remains in the

upper parts of the Upinian deposits in the Volga area near Stalingrad [24].

Immediately after these small uplifts of brief duration, a new subsidence began on the Russian Platform and adjoining regions and a much greater marine transgression began in the Tournaisian age -- the Cherepetsk transgression.

Evidence for the extent of this transgression, aside from the transgressive sedimentary deposits of this time, can be found in the composition of the brachiopod assemblage of these sediments: there was a clear and extensive influx of new types from the surrounding basins of western Europe and the region east of the Urals (table 2).

burlingtonensis, a North American species. Other representatives of western European and North American fauna -- Dielasma insigne, Linoproductus laevicostus, Athyris hirsuta, etc. -- are also widespread here. These types make up an extensive and varied assemblage which is evidence that the Cherepetsk transgression covered the barriers that had isolated the basin of the Russian Platform in Likhvinian time from adjoining regions, and also made possible a free migration of fauna between this area and the seas of western Europe and North America.

This assemblage includes types common to both the Cherepetsk strata of the Moscow basin and the Tournaisian stage of the Kuznets basin and Kazakhstan; among these might

TABLE 2. Brachiopods of the Cherepetsk stratum in the Moscow basin [19].

Schizophoria resupinata (Mart.)	Sp. taidonensis Tolm.
Leptaenella analoga (Phill.)	Sp. pentagonus Kon.
Schellwienella burlingtonesis Well.	Brachythyris peculiaris (Schum.)
Rugosochonetes hardrensis (Phill.)	Br. chouteaunensis Well.
R. znamenskensis Sok.	Palaeochoristites cinctus (Keys.)
Plicochonetes elegans (Kon.)	Syringothyris serenae Sok.
Plicatifera zyabrovensis Sok.	S. hannibalensis Swall.
Pl. tschernychini Sok.	Martinia praeglabra Sok.
Avonia (?) tscherepeti (Liss.)	Eomartiniopsis tscherepeti Sok.
Buxtonia lichwini (Liss.)	Ambocoelia urei Flem.
B. antiquissima (Liss.)	A. fissa George.
Pustula scabriculiformis (Liss.)	Punctospirifer partitus Portl.
Linoproductus laevicostus (White.)	Eumetria osagensis (Swall.)
Antiquatonia znamenskensis (Liss.)	E. perstrialis Rowley.
Camarotoechia acutirugata (Kon.)	Athyris pectinata Sem. et Moell.
Pugnoides missouriensis (Schum.)	A. hirsuta Hall.
Spirifer tornacensis Kon.	Dielasma insigne Kon.

The Cherepetsk fauna in the Moscow basin contains almost no types that are also known among the fauna of the Likhvinian substage; the only exceptions are Ambocoelia urei and Athyris pectinata, and both of these are rare in the Cherepetsk horizon. The brachiopods of Likhvinian time were apparently destroyed by the abrupt fluctuations in their environment that accompanied the formation of the Ageyev series. The faunal assemblage changed sharply during this time; there was an appearance not only of new species, but even of genera that were not represented in the Likhvinian seas of the Moscow basin -- Buxtonia, Pustula, Pugnoides, Syringothyris, Eumetria, Dielasma and others. Spirifers that had been totally absent earlier assumed a dominant position in number in the new fauna. The most widespread were Spirifer tornacensis, Rugosochonetes hardrensis, Leptaenella analoga, Punctospirifer partitus, Camarotoechia acutirugata -- types which are also common to the Tournaisian fauna of western Europe -- and Schellwienella

be mentioned Spirifer taidonensis, a species also found in the Taydon zone of the Kuznets basin, and a number of species occurring over a wide area in Kazakhstan. Among these latter, Syringothyris hanibalensis and Brachythyris peculiatis, which lived in Kazakhstan in Kassinian times, entered the basin on the Russian Platform with the Cherepetsk transgression, while Leptaenella analoga and the Spirifer tornacensis group inhabited the waters that simultaneously covered northeastern Kazakhstan and the Moscow basin.

The presence of such species as Spirifer tornacensis, Chonetes (Rugosochonetes) hardrensis and others associates the brachiopod assemblage of the Cherepetsk strata near Moscow with the fauna of the same age in other regions of the Russian Platform, the Donets basin (zone $C^{t}{}_{1}$ c), the Kuznets basin (the Taydon zone) and Kazakhstan (the lower parts of the Rusakov beds). This widespread transgression obviously occupied

not only all of the Russian Platform, but also spread over all of Eurasia from the Anglo-Belgian basin through European Russia to Asiatic Russia; the evidence for this is the fauna common to all these regions. Thus the extent of the Cherepetsk transgression is shown by the widespread association of brachiopods contained in the sediments of this time in various countries.

The next part of the stratigraphic section of the Tournaisian stage is called the Kizelovian in the Unified Scheme of Carboniferous Stratigraphy adopted in 1951. But the identification of the entire Kizelov horizon with zone $C^t{}_1$ d or the Karpov zone in the Carboniferous of the Donets area that was accepted in this Unified Scheme is not correct. It has already been said [2] that only the lower part of the Kizelov strata, which is referred to as "transitional beds" in the Krasnaya Polyana section, should be correlated with the Karpov zone ($C^t{}_1$ d); the deposits analogous to these beds were evidently identified by V.M. Pozner in the area east of the Volga as the Ikchegol' beds [15], and by N.P. Malakhova on the western slope of the Urals as the Chikmanian series [10, 11]. V.M. Pozner's Rakov beds apparently correspond to the upper part of the Karpov zone and the Chikmanian series. These subdivisions have not been accurately correlated, however, and the interrelationships of their stratigraphic boundaries are still unclear.

Among the fauna contained in this part of the section, the Foraminifera have been studied on the Russian Platform, and other groups are also known in the Urals and the Donets basin but have not yet been described in monographs; A.P. Rotay has described some of the brachiopod species from zone $C^t{}_1$ d of the Carboniferous in the Donets area [18]. At the present time it may be considered that the identification of the "transitional beds" of both sides of the Volga with the lower part of zone $C^t{}_1$ d or the Karpov zone of the Donets basin has been proved on the basis of the Foraminifera.

Deposits of this age occur on the Russian Platform along the middle and lower Volga as a thin series of limestones and clays (7 to 8 meters in all) on the right bank of the Volga in the Ul'yanov region (paper by R.M. Pistrak) and as a thicker layer of limestones interbedded with clays and containing ostracods and foraminifera in the Saratov and Stalingrad regions. The same deposits also occur in the top of the Tournaisian stage at Samarskaya Luka and in the Kuybyshev area of the Volga and in Tatary within a narrow belt that has been called the Kamsk-Kinel' depression [15]. In all these places they are deposited, with gradual transition in lithology, upon rocks of the Cherepetsk series and are composed, like the latter, mainly of limestones. There are no deposits of this time in the Moscow basin -- they were either eroded away or not deposited at all.

The above formations were deposited during the last phase of the geologic history of the Tournaisian age. The clay interbeds among the limestones, and the shallow-water nature of the limestones themselves, testify that the overall subsidence of the Russian Platform at this time had become slower, while in places new uplifts had begun and dry lands emerged, providing sources for the argillaceous material. This was the end of the tectonic regime that had covered the Russian Platform with the waters of the successive seas in Malevian, Upinian and Cherepetsk times. Thereafter, as will be shown below, at the beginning of the Visean age the general movement of the earth's crust in this area changed within a short interval of time.

Productus sublaevis Kon. (Productus humerosus Sow.) time. The sediments directly following those that have just been described are different in different places. These include the Productus sublaevis Kon. (Productus humerosus Sow.) zone or zone $C^v{}_1$ a in the Donets basin, the upper part of L.S. Librovich's Berezov suite on the eastern slope of the Southern Urals, the Kinderlinian and Kos'vinian limestones on the western slope of the Urals, and the Upper Kizelov beds or lower Malinov beds plus the lower part of the upper Malinov beds distinguished by V.M. Pozner [15], which are found east of the Volga.

The identification of the "Upper Kizelov" beds in the Volga-Ural region with zone $C^v{}_1$ a and with the Productus sublaevis zone in the Donets basin may be based on the brachiopods contained in these and other deposits. The following have been cited in this part of the stratigraphic section in the area east of the Volga: Schizophoria resupinata (Mart.), Rugosochonetes hardrensis (Phill.), Chonetes dalmanianus Kon., Megachonetes sp. of the type zimmermani Paeck., Echinoconchus punctatus (Mart.), Buchtonia cf. antiquissima Liss., Pustula cf. Pustulosiformis Rot., Pustula pixidiformis Kon., Linoproductus cf. laevicostus (White), Plicatifera aff. spelunca Nal., Punctospirifer partitus Portl., Spirifer aff. attenuatus Sow., Spirifer konincki Dew. and a number of others.

Despite the absence of Productus sublaevis itself in the material from the Ural-Volga region that has been studied up to now, this

complex contains such a large percentage of genera also found in the Productus sublaevis zone of western Europe, the Donets basin and the Urals, that this correlation is fully confirmed.[2]

In the Donets basin the Productus sublaevis zone (or zone $C^{V}1$ a) contains Productus humerosus Sow. (Pr. sublaevis Kon.), Productus humerosus var. donica Rot., Chonetes magna Rot., Chonetes dalmanianus var. tenuistriata Rot. and certain others. This assemblage is the same in the Urals sections; in the Kinderlinian limestones of the southern Urals D.V. Nalivkin [14] has found: Chonetes dalmanianus Kon., Linoproductus laevicostus (White), Spirifer konincki Dew., and Buxtonia lichwini Liss. On the western slope of the Urals D.V. Nalivkin found Pustula pixidiformis Kon., Plicatifera zilimi Nal., Pl. christini Kon., Spirifer princeps McCoy, Sp. konincki Dew., Brachythyris suborbicularis Hall., and Productus minimus Dem. In the upper part of L.S. Librovich's Berezov suite in the upper Ural River valley, D.V. Nalivkin mentions Plicatifera humerosa Sow., Pustula pixidiformis Kon., Spirifer aff. cinstus Keys., and Spirifer aff. tornacensis Kon.

There is no doubt that this brachiopod fauna and the "Upper Kizelov" series of the Volga-Ural region described above have the same faunal composition. But certain differences in the fauna between these deposits in the area east of the Volga and their analogues in other regions must be stressed. The Volga-Ural region does not contain those exceedingly large brachiopods that are found in the Kos-vinian and Kinderlinian limestones of the Urals: the gigantic convex Daviesiella comoides, the huge Plicatifera humerosa and the immense Chonetes forms that occur in the Productus sublaevis beds on the eastern slope of the Urals. Neither are there any large corals such as Caninia Mich., nor the huge Donets shells such as Chonetes magna. The absence of only these extremely large types in a faunal composition that is in all other respects common to both the deposits under consideration is clear evidence that the difference is purely one of facies.

The difference in facies can also be strikingly seen in the lithology of the rocks -- limestones in the Urals and the Donets basin, and argillites, siltstones and clays with interbedded limestones in the Kamakinel' depression, where the lower part of the series is composed of limestones in only a few places, such as in Buzuluk and Pilyugino. In view of this difference in the composition of the sediments, it is quite natural that there should be a facies difference in the fauna as well.

Because of the facies character of the Productus sublaevis zone in the Kama-Kinel' depression, the overall composition of the fauna contained in it is of interest. In addition to numerous brachiopods (which are frequently unidentifiable), these rocks have individual layers containing abundant coral, chiefly solitary. There are also remains of cephalopods -- small Orthoceratidae -- and sometimes numerous remains of goniatites in the form of thin shell fragments with nacreous layers, although these can be only rarely identified. Many ostracods are found, and limestone layers contain many foraminifera and crinoid fragments, scales and fish bones. Various groups of organisms predominate in different layers. There are some layers with only one type of fauna, such as small lingulae or orbiculoidea, but these are rare.

The numerous and varied marine fauna testify to the marine origin of these rocks. The most frequently encountered assemblages of organisms are those normally found in deep-water marine basins. The large number of thin-shelled organisms with flat valves, such as Megachonetes and Orthotethyna, which are widespread in some parts of the series, and the absence of large, heavy, thick shells indicate that this fauna lived under deep-water conditions. The manner in which the majority of specimens is preserved supports this conclusion -- the fine details of sculpturing along the valves of Pustulina and Echinoconchus, the presence of the smallest joints and long hollow spines, and in some cases even details of the internal structure all show that the shells were not transported over long distances. Complete specimens, however, are extremely rare; the valves are almost always separated and crushed, evidently as a result of the pressures involved in the lithification of the sediments. Certain layers represent accumulations of brachiopod shells amounting almost to a coquina, indicating that strong movements of water occurred in this basin. It must also be added that the abundant pyrite in these rocks, which commonly lines the shells of brachiopods, is probably of epigenetic origin, since this fauna could not have existed in a basin with an abnormal content of gases or salts and poor aeration.

In the Moscow basin and the central uplift of the Russian Platform (the Tsninsk-Issinsk-Gor'kiy block) there are no Pr. sublaevis zone deposits; these were evidently

[2] D. Ye. Ayzenverg and N. Ye. Brazhnikova base their identification of the $C^{V}1$ a zone of the Donets Carboniferous with the Kinderlinian limestones and their analogues in the Urals primarily on the foraminifera [2].

not deposited here. This part of the Russian Platform was, during this period, drawn into the tectonic uplift which caused a lengthy interruption in the accumulation of marine sediments; sediments began to accumulate again in the Tula age [8, 33] and locally in the Aleksinian age.

There are extensive Productus sublaevis zone sediments east of the Volga River, occupying the narrow strip of the Kama-Kinel' depression; somewhere, but only in its lowermost part, these deposits should appear in the Tatar anticline within the Kama-Kinel' depression, and they also occur on the northern shore of the Caspian depression, in the Buzuluk district of the Orenburg region. They are widespread as zone C^{V}_{1} a in the Donets basin and evidently in the Dnepr-Donets depression [4, 25]. These sediments have also been found on the western and eastern slopes of the Urals. Thus they extend over both the western and eastern parts of European Russia, but were apparently not deposited in the central areas of the Russian Platform.

The geographic distribution of the marine basins in early Visean time on the Russian Platform was essentially different from that of the basins in the Tournaisian age. This shows that a new phase of geologic history had begun in this territory, bringing about new distribution of zones of uplift and subsidence.

The fauna of the Productus sublaevis zone differs strikingly from that of the underlying deposits. In contrast to the transitional and the Rakov beds -- the analogues of the Karpov zone in the Donets Carboniferous -- which contain a large percentage of foraminifera species common to the Cherepetsk series as well, the Productus sublaevis zone fauna has almost no Cherepetsk types among its foraminifera. There are some types also found in the Karpov zone, but only those which appear for the first time in the Karpov zone and its analogues. The Productus sublaevis zone has the following brachiopod species in common with the Cherepetsk series: Chonetes hardrensis, Punctospirifer partitus, Buxtonia lichwini, Buxtonia antiquissima, and Spirifer aff. cinctus Keys, which is close to the Cherepetsk form.

There are many Western European species among the brachiopods of the Productus sublaevis zone in the Donets basin, the Volga-Ural region and in the Urals: Productus sublaevis, Spirifer konincki, Sp. attenuatus, Pustula pixidiformis, Punctospirifer partitus, Megachonetes type zimmermanni, Megach. ex gr. papilionacea and others.

The proportional number of western European species in this fauna is greater th in the Cherepetsk fauna. Such forms as Pustula pixidiformis, Megachonetes, Chonetes dalmanianus and other Western European species are the most widespread in this fauna and are frequently represented by massive specimens. The brachiopods of this complex in the Volga-Ural region have not yet been described in monographs; thus it is possible that certain types which are now considered to be resembling Western Europe species (Megachonetes type zimmermanni and others) may be classified as independent speci Nevertheless, there is no doubt that this zone has a large percentage of brachiopod species i common with Western Europe. This shows tha there was a lively interchange of fauna betwee the basins in Russia and those in Western Europe; the channel of communication was pro ably somewhere to the south.

THE BOUNDARY BETWEEN THE TOURNAISIAN AND THE VISEAN STAGES

The sharp change in fauna with the beginning of Productus sublaevis time, the greate variety in the assemblages of both brachiopods and other groups, the redistribution of marine basins on the Russian Platform, and the change in tectonic activity in certain parts of the area as compared to that of the Tournaisian age are all evidence that the lower boundary of the Productus sublaevis zone marks a natural turning point in the geologic history of an extensive area. It also agrees closely with the boundary betwee the Tournaisian and Visean stages as adopted in Western Europe, in the Donets basin, on the eastern slope of the Southern Urals and in a number of other places.

The attribution of this zone to the Tournaisian stage [14] and the location of the upper boundary of the Tournaisian stage along the top of this zone, as has been done in some parts of the Urals and in the Volga-Ural region, does not accord with all the geologic facts that are known at present.

The beginning of Stalinogorsk time. Assigning the Productus sublaevis zone to the Visean stage is not equivalent to including it in the Stalinogorsk series. There are too many geologic events that took place after this time and are indicated in the change in the faunal assemblage. In the Donets basin, in the transition from zone C^{V}_{1} a to zone C^{V}_{1} b, Plicatifera humerosa and the forms close to it disappeared, as did Chonetes dalmanianus, while Spirifer grabovi Rot. and Athyris assinuata Liss. made their appearance and the coral population changed radically in composition. In the Volga-Ural region the rocks containing the Productus sublaevis marine fauna are over-

TABLE 3. Correlation of the Stratigraphic Subdivisions in the Lower Part of the Lower Carboniferous in the Volga-Ural region, the Donets basin, and the Moscow basin.

<table>
<tr><th colspan="2">Regions</th><th colspan="3">Volga-Ural region</th><th colspan="2">Donets basin</th><th>Moscow basin</th></tr>
<tr><th>Stage</th><th>Substage</th><th colspan="2">Subdivisions adopted in this article</th><th>Subdivisions adopted for the same deposits in other papers</th><th colspan="2">D. Ye. Ayzenverg and N. Ye. Brazhnikova, 1956</th><th>Correlation with Donets Carboniferous by D. Ye. Ayzenverg and N. Ye. Brazhnikova, 1956</th></tr>
<tr><td rowspan="3">Visean</td><td rowspan="3">Yasnopolyanian</td><td>Stalinogorsk stratum</td><td></td><td></td><td colspan="2">C^V_1l
C^V_1c</td><td>Coal-bearing series</td></tr>
<tr><td rowspan="2"></td><td>Sandy stratum with spores
Erosion</td><td>Two upper subdivisions of V. M. Pozner's Upper Malinov series</td><td>C^V_1b</td><td>Ol'gin series</td><td rowspan="2">Hiatus</td></tr>
<tr><td>Productus sublaevis Kon. (= Productus humerosus Sow.) zone</td><td>V. M. Pozner's Lower Malinov and the lower subdivision of his Upper Malinov stratum</td><td colspan="2">C^V_1a</td></tr>
<tr><td rowspan="2">Tournaisian</td><td rowspan="2">Chernyshinian</td><td>Kizelov stratum</td><td>Rakov beds "Transitional beds" of Krasnaya Polyana</td><td>Rakov beds V. M. Pozner's Ikchegol' stratum</td><td colspan="2">C^t_1d (Karpov zone)</td><td>Erosion</td></tr>
<tr><td>Cherepetsk stratum</td><td>Cherepetsk stratum</td><td>Cherepetsk stratum</td><td colspan="2">Zone C^t_1c</td><td>Cherepetsk stratum</td></tr>
</table>

lain by a sandy layer which V.M. Pozner [15] assigns to the upper Malinov and which the paper by S.V. Semikhatova, L.M. Yelina and A.A. Ryzhova in 1956 places within the Stalinogorsk series. This layer in places expands to 400 meters in thickness, in others it diminishes to 100 meters, and frequently disappears from the section entirely. With the exception of one or two clay intercalations containing Lingula, there are no remains of marine organisms and the layer is composed almost entirely of sediments of continental origin. The evidence for this is the sharp changes in thickness, the presence of cross-bedding and the absence of organic detritus, except for spores and plant pollen. It is interesting that, according to T.V. Byvsheva, the Spirifer konincki and Pustula pixidiformis rocks contain a different group of spores than does this sandy layer, and that the latter contains a different group from that of the overlying rocks of the Stalinogorsk horizon, which contain the same assemblage of spores (at Buzuluk) as the lower part of the Stalinogorsk series in the vicinity of Moscow. Can this sandy layer be considered as the basal formation of the Stalinogorsk series? The answer to this question depends to a great extent on the degree of difference between the assemblage of spores and pollen in this layer and the first spore and pollen assemblage of the Stalinogorsk series distinguished by S.N. Naumova; these relationships require further study.

From what has been said above it follows that the Unified Scheme of Carboniferous Stratigraphy of 1941 [sic], which is correct for most of the stratigraphic section, must be reconsidered as regards the geologic age and the correlation of the Kizelov series. The scope of this series must be decreased to include only the Tournaisian beds -- the "transitional beds" of Krasnaya Polyana and the Rakov beds; the deposits of the Productus sublaevis zone, which in the Unified Scheme of 1951 were included in the Kizelov series, must be given another name, since they belong not to the Tournaisian but to the Visean stage (table 3).

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All-Union Scientific Research Institute of Geologic Oil Prospecting, Moscow

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ON THE STRATIGRAPHY OF THE FRIABLE FORMATIONS OF THE ZEYSKO-BUREINSKAYA DEPRESSION

by

V. I. Fin'ko and Ye. D. Zaklinskaya

ABSTRACT

Previously existing stratigraphic breakdowns of the sequences of friable formations in the Zeysko-Bureinskaya depression are subjected to a critical examination. On the basis of geologic, lithologic, and paleobotanic data a new stratigraphic plan for the friable Tsagayanskaya formations of the Zeysko-Bureinskaya depression is proposed. They are to be classified as the Tsagayanskaya series. The series, in turn, is divided into suites: the Vodorazdel'naya (Oligocene), the Kivdinskaya (Paleocene-Eocene), and the Tsagayanskaya (Upper Cretaceous).

* * * * *

The Zeysko-Bureinskaya depression is a large Meso-Cenozoic basin which has been filled by a thick series of horizontally bedded, continental, Upper Cretaceous and Tertiary deposits (fig. 1). The present-day appearance of the depression results from Upper Cretaceous and Tertiary tectonic block movements of varying degree which affected extensive complexes of Archean, Proterozoic, Paleozoic, and Mesozoic sediments. These were consolidated into rigid platform areas during Precambrian, Proterozoic, Paleozoic, and Mesozoic folding. The block movements created a mountain zone bordering the depression, and an extensive region of relative subsidence -- the Zeysko-Bureinskaya depression. During the Upper Cretaceous and Tertiary the depression served as a zone of aggradation, accumulating detritus from the surrounding mountain ranges.

The basement of the Zeysko-Bureinskaya depression is composed of complexes of igneous, metamorphic, and sedimentary rocks of varying age from Archean and Proterozoic to Upper Jurassic and Lower Cretaceous inclusive.

In the central and southern part of the depression the absolute depth of the friable formations has not been determined.

Recent geophysical studies on the deep structure of the Zeysko-Bureinskaya depression have shown that the thickness of friable deposits is approximately 3,000 meters in the central area. This is only an estimate however, since it is not verified by drilling. The deepest drilling, near Raychikhinsk, shows the thickness to be at least 306.7 meters.

The series of friable, horizontally-bedded, continental formations filling the depression are, for the most part, white quartz-feldspar non-uniform, cross-bedded sands which grade into pebble beds and less frequently conglomerates. These latter do not have wide distribution, however, and occur only in the lower part of the series. This series of quartz-feldspathic sands is interbedded with layers of fire-resistant kaolinite, hydromica, monothermic and montmorillonitic clays, brown coal and lignite. These form several horizons which occupy a definite stratigraphic position in the cross-section of friable deposits. Most characteristic is the prevalence of white-hydromica, which acts as a partial cement for the sandstone.

Generally a cross-section of the depression shows a steady increase in the amount of kaolin from top to bottom.

The cross-bedding of the sand series and the unusual variation in uniformity of bedded material is explained by the fact that the series was not formed through one continual process, but rather by periodic actions of large-scale water flows which carried great amounts of material for a short distance and quickly deposited it before withdrawing to the forehills.

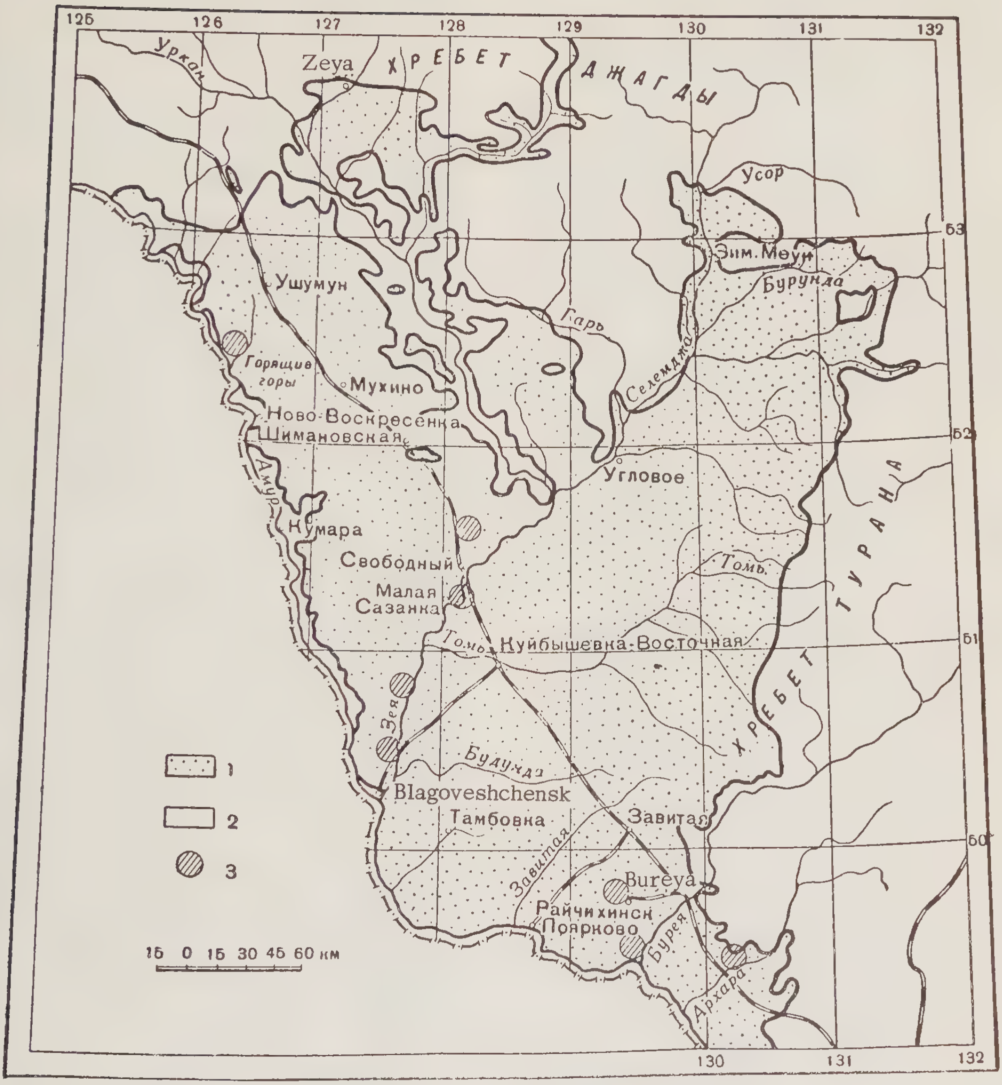


FIGURE 1. Diagram map of the friable deposits of the Zeya-Bureyan depression.

1 - Friable deposits; 2 - Foundation of the depression;
3 - Points where the main profiles studied from 1955 to 1956 are found.

The sequences of friable formations which fill the Zeysko-Bureinskaya depression were first called Tsagayanskaya by P.K. Yavorovskiy [20]. For a long time these formations and those of the neighboring regions of Amur River area were thought to be Tertiary and even Miocene on the basis of O. Geyer's estimate of the age of flora gathered from the mouth of the Bureya River by F.B. Schmidt.

S.V. Konstantov [13, 14], describing flora from the same locale at a considerably later time, also considered them Tertiary, but lowered the age to Eocene. P.K. Yavorovskiy [20], examining the sandy-clay alluvial Tsaganskaya formations of the Amur River area as a single geologic cycle of deposition, and taking into account the friabilites and horizontal bedding, considered them to be Tertiary on the basis of the prevailing idea that their flora was of Tertiary age.

Later, as the result of the works of A.N. Krishtofovich [7-11], A.N. Ryabinin [17, 18], A.I. Poyarkova [16], T.N. Baykovskaya [1], M.O. Borsuk [4], and S.A. Muzylev [15] it was established that the deposits of the Zeysko-Bureinskaya depression were made up of sediments of various ages embracing a period of time from the Upper Cretaceous to the Miocene (?) inclusive. In one of his later works A.N. Krishtofovich [9], after discovering not only Upper Cretaceous but gradual transition specimens of the lower Tertiary (Paleocene) deposits, wrote: "In the Amur basin, as in North America, the Laramie problem rises to full measure. Here, as well as there, considerable work has been expended to solve it; doubtless much more will have to be done in this regard. The experience of North America shows how complicated the problem is. The long-standing Laramie problem was only recently cleared up by the discovery of the Kennon-Bol marine beds in Dakota. These were marked by characteristic Upper Cretaceous fauna and facilitated the identification of the Fort Union suite as definitely Tertiary and Paleocene as distinguished from the Lens suite which was Upper Cretaceous."

A.N. Krishtofovich explains the difficulties in solving the problems of Laramie stratigraphy as resulting from the uniformity and unbroken nature of the deposits between the Tertiary and Cretaceous periods and by the considerably more meager variety of flora and fauna developed during a long period of uniform conditions. Analogous difficulties occur in attempting a stratigraphic breakdown of the friable continental Tsagayanskaya deposits of the Zeysko-Bureinskaya depression.

In 1941-43 S.A. Muzylev compiled a geologic map with a scale of 1:1,000,000 of the southern part of the depression. These investigations helped to introduce much new information to our knowledge of the stratigraphy of the Zeysko-Bureinskaya depression.

On the basis of the paleobotanic works of T.N. Baykovskaya [1, 2], A.N. Krishtofovich [7-10], M.O. Bursuk [4], and his own investigations, S.A. Muzylev proposed his plan for the stratigraphic breakdown of the Zeysko-Bureinskaya depression.

S.A. Muzylev divides this complex into two unequal series of different ages: the lower - the Tsagayanskaya which includes the Kivdinskaya suite, and also an upper, lying discordantly upon the Tsagayan and the Kivdinskaya suite, a series of upper or Vodorazdel'nyye sands, which the author assigns to the Neogene.

In the plan proposed by S.A. Muzylev the Tsagayanskay sequences can no longer be considered as being composed only of Upper Cretaceous deposits but, since it includes the Kivdinskaya suite, it must be considered to be of dual age. Its lower part, including the coal beds, still belongs to the Upper Cretaceous, and the upper, the part above the coal beds, belongs to the Paleocene. But, at the same time, S.A. Muzylev's plan does not designate the entire sequence as the Tsagayanskay series, as had already been suggested by P.K. Yavorovskiy. Since "Tsagayanskay suite" had already been rooted in the literature as being the name of only the Upper Cretaceous deposits, by A.N. Krishtofovich, the assignment of a new meaning to this designation led to considerable confusion. Finally, S.A. Muzylev's distinction between the Tsagayanskay series and the suites of the Vodorazdel'nyye sands, which resembled each other in lithologic composition and were separated only by an insignificant break, is not at all justified geologically.

Notwithstanding the significant advances of recent years, the Zeysko-Bureinskay deposits remain relatively unstudied, both insofar as physical composition and paleontological and paleobotanical characteristics are concerned. Since the lithologic composition is unusually uniform, and faunal remains are practically nonexistent, the breakdown into suites is done chiefly on the basis of paleobotanic data. The age, boundaries, and interrelations of the identified suites are not yet clear and purely conditional. Consequently, there is no sufficiently well-founded and generally accepted plan for a stratigraphic breakdown of these deposits.

The stratigraphic plan proposed by

S.A. Muzylev suffers from several shortcomings. The most important of these is that the deposits which are, geologically speaking, a single complex laid down over a long period, are not studied as a unit, but are artificially divided into two distinctive series: the lower Tsagayanskaya, and the upper -- the series of Vodorazdel'nyye sands.

Further, the very designation "Tsagayanskaya series" loses concrete significance in this plan, since it is not used by Muzylev either in the same sense that it was used by Yavorovskiy to designate the entire complex of friable deposits in the depression, or with the same meaning which the designation "Tsagayanskaya suite" or "Tsagayanskaya stage" had in Krishtofovich's works. This investigator gave the designation a narrow stratigraphic significance and meant only that part of the depression which was marked by Upper Cretaceous flora and fauna. Under the designation Muzylev identifies sequences of different ages embracing Upper Cretaceous and Tertiary formations which do not, however, include all the deposits of the depression.

Supplementary material on the stratigraphic and petrographic characteristics of the deposits was received in 1953-1956. This permitted a more exact dating of individual suites and showed that the Vodorazdel'naya suite is inseparable from the underlying deposits. On this basis, using the data of previous investigators (Yavorovskiy, Krishtofovich, Baykovskiy, Muzylev), and from the new facts it was possible to propose a new stratigraphic plan.

The most widespread of all the deposits in the Zeysko-Bureinskaya (and also the Upper Zeyskaya) depression is the series of cross-bedded sands (Vodorazdel'naya suite according to Muzylev) which were deposited on older formations, including the Kivdinskaya suite, on a scoured erosion surface.

In the Vodorazdel'naya sands there are older formations containing lenses of fire clay, usually accompanied by lignite layers. These lenses of lignite and fire clay form two sufficiently sharply-defined, but interrupted horizons in the Vodorazdel'naya suite. The thickness of each horizon is 3 to 5 meters, and they are separated by 15 to 20 meter beds of sand. The lower horizon rests 35 to 40 meters above the floor of the suite. The consistency of the cross-sections of this suite was remarkable.

Cross-sections of the right bank of the lower Zeya River amazingly resembled those of the same suite on the Amur River near the so-called Goryashchiye Mountains at a distance of more than 300 kilometers. Here the horizons of fire clays and lignites also rested 35 to 40 meters above the floor of the suite. Near the Goryashchiye Mountains on the Amur, the Vodorazdel'naya suite filled a well-formed ancient valley, and the similarity of its cross-section with the stream bed alluvium is quite clear since the sediments had been laid down in a well-formed valley, and because of their subsequent change in vertical and horizontal directions. Other cross-sections taken over a broad area reveal their similarity less sharply.

The presence of the two horizons, the fire clay and the lignite in the cross-section of the Vodorazdel'naya suite near Goryashchiye Mountains in exactly the same position as in other cross-sections of this suite attests to a single tectonic regime embracing a wide area. The general thickness of the formations of the Vodorazdel'naya suite reaches 100 to 120 meters.

The cross-section of the Vodorazdel'naya suite formations near Goryashchiye Mountains (Smirnovka on the Amur) proceeds from the lower to the upper horizons, as follows (see Fig. 2):

1. Granites and fresh diabases; thickness 3 meters.

2. The same granites and kaolinied diabases; thickness 20 meters.

3. Basal beds of the Vodorazdel'naya suite consisting of roughly rounded boulders (up to 1.5 meters in diameter) and pebbles of adjacent weathered granites and diabases; thickness 5 to 8 meters.

4. Bed of white, quartz-feldspathic cross-bedded sands with quartz and chalcedony pebbles; sands contain from 10 to 15 percent kaolin-hydromicaceous material; thickness 46 meters.

5. Brown-gray plastic clays with a great quantity of carbonized plant remnants; thickness 2 meters.

6. Lignite; thickness 1.2 to 1.5 meters.

7. Sand beds, analogous to those of layer 4; thickness 12 to 15 meters.

8. Light brown plastic clays; thickness 0.3 meters.

9. Lignite; thickness 0.25 meters.

10. Brown plastic clays; thickness 1.8 meters.

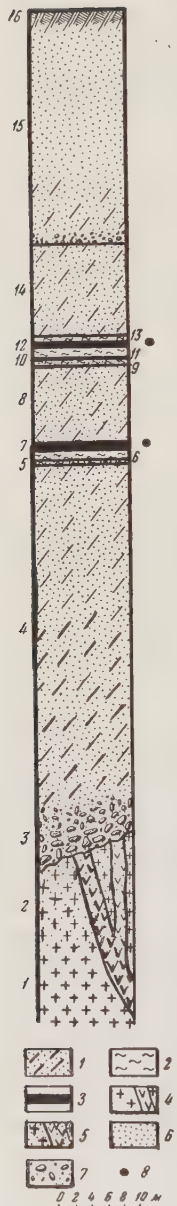


FIGURE 2. Profile of the Vodorazdel'naya sand series. Goryashchiye Mountains, Smirnovka area on the Amur.

1 - Quartz-feldspathic sands; 2 - Monothermite clays; 3 - Lignite; 4 - Granite and diabase; 5 - Kaolinized granite and diabase; 6 - Quartz-feldspathic sands, weakly ferruginous; 7 - Pebble and conglomerate; 8 - Point where samples were taken for spore-pollen analyses.

11. Lignite; thickness 1 meter.

12. Black plastic clays with a great quantity of plant detritus; thickness 0.3 meters.

13. White quartz-feldspathic, cross-bedded sands analogous to those of layers 4 and 7; thickness 1.2 meters.

14. Quartz-feldspathic, cross-bedded, ferruginous sands; thickness 32 meters.

Analogous cross-sections of the Vodorazdel'naya suite taken from the right bank of the Zeya River near Malaya Sazanka, Belogor'ye, and Moskvitino were studied. A comparison of the sections is given in Fig. 3, and data from a spore-pollen analysis is presented in Table 1.

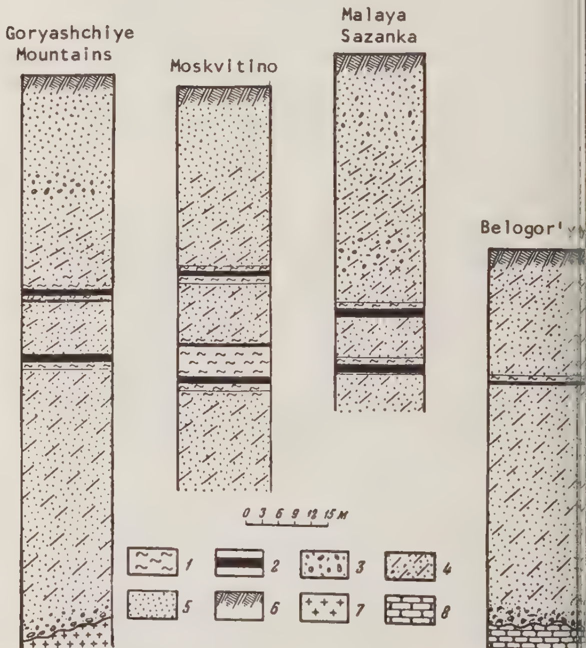


FIGURE 3. Diagrammatic comparison of deposit profile of the Vodorazdel'naya sand series.

1 - Refractory clay; 2 - Lignite; 3 - Pebble and conglomerate; 4 - Quartz-feldspathic sands with kaolin cement; 5 - Arkose sands; 6 - Humus-vegetation cover; 7 - Granite; 8 - Sandstones of the Tsagaian series.

It is interesting to note that G. Ye. Bykov [5, 6] in studying the lignite horizons in the upper Zeyskaya depression designated the friable deposits which fill the depression as Soktakhanskaya suite. According to his data, this suite was laid down very discordantly upon the Jurassic coal-bearing and older formations, and is marked by cross-bedded sands with layers of clay and lignite.

TABLE 1. Results of spore-pollen analyses of clays and lignites from the Vodorazdel'naya series of the Goryashchiye Mountains; lignites from the Buzuli refractory clay deposit; and lignites of the Soktakhanian series of the upper Zeya-Bureya depression.

(From profiles in the Goryashchiye Mountains and Buzuli analyzed by I.Z. Kotova and from the Soktakhanian series analyzed by E. Smirnova.

Location	Goryashchiye Mounts[1]			Buzuli	Upper Zeya Depression
Comments	Sample 212/55	Sample 216/55	Sample 218/55	Sample 70/54	Lignite from the Soktakhanian Series
1	2	3	4	5	6
Gymnosperm pollens	25.5	55.0	23.5	6.0	8.0 - 90.0
Angiosperm "	74.0	31.5	76.0	60.0	22.0 - 59.0
Spores of Pteridphytes, Mosses, and Liverworts	0.5	13.5	0.5	34.0	-
Composition of the gymnosperm pollens[2] (in percent)					
Pinaceae					
Keteleeria sp.	1.5	--	3.0	--	--
Abies sp.	--	1.0	7.0	--	0 - 4.5
Picea sp.	14.0	15.0	14.5	--	0 - 25.0
Pinus sect. Cembrea	--	7.0	--	11[3]	
Pinus aff. koraiensis	9.5	1.5	3.0	--	--
P. sibiriciformis Zakl. (poll.)	2.0	--	4.0	--	--
P. sect. Strobus.	0.5	--	--	--	--
P. aff. silvestris	70.5	-0	--	--	4.0 - 48.0
Pinus sp.	0.0	68.5	50.0	8[3]	4.0 - 13.0
Tsuga sp.	7.0	7.	18.5	2	0 - 3.5
Composition of the spores (grain quantity)					
Potamogetonaceae	1.5	--	4.5	--	--
Sparganiceae	--	--	2.0	--	--
Cramineae	--	1.0	--	--	--
Salicaceae					
Salix sp.	0.5	1.0	1.0	--	--
Myricaceae					
Myrica sp.	7.5	--	1.0	1.0	--
Fagaceae					
Fagus sp.	--	3.5	1.0	--	0.5 - 4.0
Quercus sp.	--	--	1.0	--	--
Castanea sp.	0.5	--	--	--	--
Juglandaceae					
Juglans sp.	2.0	2.0	1.0	3.0	0 - 3.0
Carya sp.	--	2.5	1.5	0.5	--
Pterocarya sp.	--	--	1.0	--	0 - 2.0
Betulaceae					
Betula sp.	34.5	45.0	36.0	0.5	18.0 - 35.0
Alnus sp.	21.0	2.5	10.0	77.5	2.0 - 12.0
Carpinus sp.	0.5	1.0	2.0	--	--
Corylus sp.	7.0	4.5	0.5	1.0	--
Ostrya sp.	5.0	--	1.0	1.0	--

TABLE 1. (continued)

Location	Goryashchiye Mounts			Buzuli	Upper Zeya Depression
Comments	Sample 212/55	Sample 216/55	Sample 218/55	Sample 70/54	Lignite from the Soktakhanian Series
1	2	3	4	5	6
Ulmaceae					
Ulmus sp.	3.0	2.0	5.0	2.5	--
Aceraceae					
Acer sp.	--	--	3.0	--	--
Aquifoliaceae					
Ilex sp.	12.0	5.0	2.5	4.5	0 - 2.0
Anacardiaceae					
Rhus sp.	--	--	--	0.5	--
Tiliaceae					
Tillia sp.	1.5	--	--	--	0 - 1.5
Nyssaceae					
Nyssa sp.	--	--	0.5	--	--
Ericaceae	2.5	18.0	--	1.5	--
Onagraceae	+	1.0	--	--	--
Caprifoliaceae	+	--	1.5	2.0	--
Leguminosae	--	--	4.0	--	--
Polygonaceae	--	--	--	0.5	--
Plumbaginaceae	--	--	0.5	--	--
Chenopodiaceae	--	1.0	--	--	--
Crassulaceae	--	--	17.5	--	--
Rosaceae	--	--	+	--	--
Euphorbicaeae	--	--	--	0.5	--
Zygophyllaceae					
Nitraria sp.	--	--	--	0.5	--
	1.0	9.5	--	4.5	--

Composition of the angiosperm pollens (in percent)

Polypodiaceae	3	41	2	38	--
Lycopodium sp.	--	3	--	--	--
Osmunda sp.	--	--	1	9.0	--
Sphagnum sp.	--	2	--	--	--

[1]Sample 212/55 is connected with the lower lignitic seam, samples 216/55 and 218/55 to the upper seam of lignite.

[2]The percentage content of the components in the analysis of E. Smirnova are calculated relative to the average sum of all the pollen grains.

[3]Instead of the percentage content, the quantity of grains is shown.

The presence of kaolin material in the sands is characteristic of the Soktakhanskaya suite. It serves to partially cement it. G. Ye. Bykov divides the suite into two beds: the lower -- clay and carbon-bearing, and the upper or sandy. On the basis of spore-pollen analyses of the clays and lignites he estimates the age of the suite as Oligocene. The spore-pollen spectra of the Soktakhanskaya and Vodorazdel'naya suite lignites are very close (see Table 1), and their formation is doubtlessly analogous.

Still older layers of unconsolidated deposits (Kivdinskaya suite) have been uncovered in the open pits of the Kivdo-Raychikhinkoye brown coal deposits. From here come the numerous, well-known imprints of flora described by Krishtofovich [8-10], and Baykovskaya [1], which these investigators have assigned to the Paleocene. A cross-section of these formations is shown in Fig. 4. Results of the spore-pollen analysis are presented in Table 2.

Proceeding from the upper to lower horizons in the central part of the Kivdo-Raychikhinskoye brown coal deposits (open pit mine of the Allochkin spur), we find:

1. A bed of sands of the Vodorazdel'naya suite laid down on a scoured erosion surface of the underlying formations; thickness 15 to 17 meters.

2. Yellow and white kaolin, mica, slightly sandy clays; thickness 3 to 8 meters.

3. Montmorillonite clay, waxy, pistachio green color; thickness 1 meter.

4. Bed of yellow and white sandy kaolin clays with poorly preserved remnants of swamp vegetation; thickness 3.7 meters.

5. White quartz-feldspathic sand with kaolin cement, cross bedding, various sized grains -- from fine to large, at times with layers of pebble and gravel; thickness 19 to 20 meters.

6. White kaolinitic clay with large spots of yellow clay, bedded; thickness 0.1 to 0.2 meters.

7. White quartz-feldspathic sand analogous to layer 5; thickness 4.5 to 5 meters.

8. Kaolin clay, in the lower part brown or reddish with ferric oxides in bright red, yellow, and violet colors; in the upper part white, slightly sandy. Laid down in the form of lenses, the thickness of which varies from 6 and 7 to 0 meters; thickness 6 meters. Sample 160/53 was taken 4.5 meters above the coal roof, sample 279/54

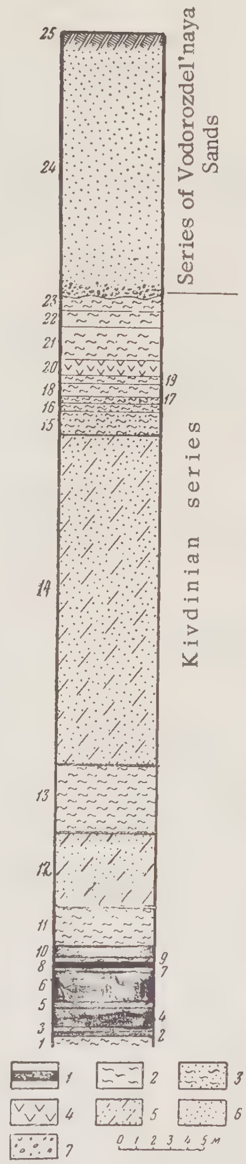


FIGURE 4. Profile of deposits of the Kivdinian series.

1 - Brown coal; 2 - Refractory, hydromicaceous, kaolin clays; 3 - Sandstone, hydromicaceous kaolin clays; 4 - Montmorillonite clays; 5 - Quartz feldspathic sands with kaolin cement; 6 - Quartz-feldspathic sand of the Vodorazdel'naya series. Basal horizon (pebble of the Vodorazdel'naya series).

TABLE 2. Results of the spore-pollen analyses of the friable portions of the Raychikhinsk brown coal deposit.

(Analysis by E.Z. Kotova)

Location of Samples in the Profile	Below the one meter coal bed	Roof of the one meter coal bed	Foot of the five meter coal bed	Clay seams of the five meter coal bed	Clays covering the coal layer
1	2	3	4	5	6
No. of samples	308/54	140/53	137/53	256/54, 257/54, 279/54	160/53
Total spore and pollen grains	159	132	209	169, 198, 187	70
Gymnosperm pollen	35.0	7.5	2.0	2.5 - 19.5	4.0
Angiosperm pollen	16.0	7.5	48.0	6.5 - 26.5	92.0
Spores of Pteridophytes, mosses and liverworts	49.0	85.0	50.0	64.0 - 91.0	4.0
Composition of Gymnosperm pollens, percent					
Cycadaceae	2.0	--	--	--	--
Ginkgoaceae	8.0	--	--	--	--
Podocarpaceae					
Podocarpus sp.	5.0	--	--	+ - 1	--
Taxaceae	1.0	--	--	--	--
Pinaceae					
Pinus sect. Strobus	26.0	9	6	2 - 12	1
Cedrus sp.	3.0	1	--	+ - 1	--
Picea sect. Omorica	--	--	--	+ - 3	--
Taxodiaceae					
Sequoia sp.	50.0	--	--	2 - 22	1
Cupressaceae	5.0	--	--	--	--
Composition of Angiosperm pollens, percent					
Salicaceae					
Salix sp.	--	--	7.0	+ - 1[1]	3[1]
Myricaceae					
Myrica sp.	5	6	37.0	3 - 18	7
Fagaceae					
Quercus sp. (2 sp.)	--	--	--	--	2
Engelhardtia sp.	--	--	--	--	1
Iuglandaceae					
Carya sp.	--	--	--	--	3
Betulaceae					
Betula sp.	4	--	9.0	1 - 7	--
Alnus sp.	5	3	16.0	+ - 2	3
Carpinus sp.	--	--	4.0	--	2
Corylus sp.	1	--	--	+ - 2	1
Ostrya sp.	1	--	--	--	--

TABLE 2. (continued)

Location of Samples in the Profile	Below the one meter coal bed	Roof of the one meter coal bed	Foot of the five meter coal bed	Clay seams of the five meter coal bed	Clays covering the coal layer
1	2	3	4	5	6
Ulmaceae					
Celtis sp.	--	--	--	--	1
Ulmus sp.	3	--	5	--	1
Anacardiaceae					
Rhus sp.	--	--	--	--	3
Rhamnaceae (Paliurus sp., Rhammus sp., Zizyphus sp.)	--	--	--	+ - 1	--
Ericaceae	--	--	--	--	2
Moraceae					
Ficus sp.	--	--	4.0	--	--
Proteaceae	--	--	--	--	2
Platanaceae					
Platanus sp.	1	--	--	--	--
Valerianaceae	--	--	--	--	2
Nelumbonaceae					
Nelumbo sp.	6	1	18.0	0 - 32	29
Composition of spores (quantity of grain)					
Polypodiaceae and Osmundaceae	63	111	103	112 - 161	2
Undetermined spores with a three rayed groove	11	1	--	0 - 10	2

[1] Instead of percentage content, the quantity of grain is given.

directly from the roof of the coal bed.

9, 11, 13, 15. The Moshchnyy 5-meter thick coal bed which is being worked at the Raychikhinskoye deposit. Within the coal bed are three well preserved layers of clayey sediments (10, 12, 14) 0.12, 0.08, and 0.03 meters thick, respectively. The first bed is located 0.8 meters from the roof, the second 0.5 meters lower than the first, and the third 1.7 to 1.8 meters below the second and 1.7 meters from the floor of the coal bed; overall thickness of the coal bed is 5 to 6 meters.

16. Dark grey or brown, dense clay with minor coal inclusions; thickness 0.3 meters.

17. Brown coal; thickness 0.3 to 1 meter.

18. Brown fatty clay with small chunks of coal; visible thickness 0.6 meters.

A 300-meter thick clay formation containing admixed sand and two thin brown coal beds occurs in the lower Kivdo-Raychikhinskoye deposits. In the Arkharo-Boguchanskoye brown coal deposit six coal beds with thickness of from 0.1 to 2.1

meters were discovered beneath a 10-meter coal bed (analogous to the commercial deposit of Raychikhinskoye), as a result of drilling. The areal extent is approximately 70 meters.

Still older unconsolidated formations (Tsagayanskaya suite) are known only in the southern and southeastern parts of the Zeysko-Bureinskaya depression where they were discovered under the roof of younger formations along the Bureya, Amur, and Arkhara Rivers by borehole drilling. These formations are represented by the same sandy-clayey series whose thickness very probably exceeds 1,000 meters.

The lowest horizons of unconsolidated formations of the Zeysko-Bureinskaya depression were uncovered on the Chinese side of the Amur. Dinosaur and Estheria fauna were found here as well as much flora [see 7-9, 17, 18].

As the result of these finds the age of the lower part of the cross-section has been identified as Upper Cretaceous (Cenonian-Danian).

It is impossible to use the results of the spore-pollen analyses (tables 1 and 2) for broad reconstructions, but they are important as factual evidence.

While not dwelling in detail on the analysis of the spore and pollen lists which include a relatively small number of species, we would note only that these species are predominantly temperate flora; the small number of exotic forms, which could be interpreted as representing formations of Cretaceous age, are insignificant here. The spore-pollen spectra of samples taken from layers adjacent to the coal beds, and also from the clays which transsect and overlay the upper 5-meter coal bed (Raychikhinskoye brown coal deposit) resemble each other closely. They differ from each other to a greater or lesser degree by the presence of the pollen families Myricaceae, Cycadaceae, Taxodiaceae, but they all contain a considerable number of genus Betula, Alnus, Carpinus, and Corylus, and, with a few exceptions, contain no pollen or spores from the Mesozoic.

The spore-pollen spectrum from the clays covering the coal bed differs from the spectrum of the coal bed inasmuch as it contains xerophytes Rhus and lacks almost completely pteriphyte spores.

The spectra from the lignites of the Goryashchiye Mountains differ considerably in composition from the spectra of the Raychikhinskoye deposit. Among the genera represented in these spectra (see Table 1) the Amentaceae predominate; there is a large number of pollen of the genera Alnus, Betula, Ilex, and a relatively large variety of species of genera Pinus, and Tsuga.

These spectra contain many genera common to Oligocene spectra, identified by M. A. Sedova [19] from various deposits in the Khasanskiy, Suputinskiy, and other regions of the Amur River area. Representatives of Turgayskaya flora Alnus, Fagus, Quercus, Ulmus, Juglans, Tilia, Acer, Pterocarya, and Liquidambar are typical for these spectra.

In analyzing the data of the spore-pollen spectra to solve stratigraphic questions of the opinion evolved recently claiming Cretaceous age for the coal-bearing strata and overlying sediments of the Zeysko-Bureinskaya depression was not confirmed. A comparison of the lists compiled by different investigators after studying the imprints of plants with lists compiled on the basis of spore-pollen analysis shows that it is difficult to ascertain the age of the horizons which contain them.

The divergence of the data, notwithstanding the variety of forms they represent, and the constant difference in their visible compositions, severely complicates the business of identifying the complexes characteristic of the individual horizons. We need only recall the flora of Raychikhi studied at different times by Krishtofovich [9, 10] and later by Baykovskaya [1]. These lists do not contain a single common species, but they do reflect a common xerophyte type which distinguishes them from flora uncovered in the underlying coal beds.

At the same time the "Raychikhinskiye" flora and fauna from the coal beds genuswise are quite similar in generic content as shown both by spore-pollen spectra and the findings of Krishtofovich [9, 10] and Baykovskaya [1]. Does this not indicate an historical affinity rather than a separation in time?

In studying the stratigraphic arrangement of the friable deposits of the Zeysko-Bureinskaya depression, where fossil flora is the sole basis of judgment, it seemed to us important to reinterpret the fossil flora uncovered by us and recorded in past studies.

Relying on genera which made possible a comparison of the leaf and pollen flora, we attempted to analyze the geographic aspect of the flora. Since the overwhelming majority of the genera present in the flora are known in today's flora world, and since their areal distribution in certain instances does not correspond to the places where they

were found, it seemed possible to establish as stratigraphic boundaries those intervals of time when these genera retreated from their Tertiary and Mesozoic (?) habitats.

Using data gotten from spore-pollen analyses, and comparing them with earlier finds of leaf flora and fauna, it was possible to compile the following basic table locating all known finds in a cross-section of the unconsolidated formations of the Zeysko-Bureinskaya depression (table 3).

This table intentionally does not set up a new dating index, since all necessary information is not yet on hand.

In conjunction with the table which shows data on flora and fauna along a vertical axis we used the general list of plant genera and species known for each horizon and compiled in Baykovskaya's work [3, pp. 129, 130, 131, 132]. We added to this data on microscopic fossils both data on spore and pollen as well as data from Krishtofovich [7-11], Borsuk [4], and other investigators [22] on macroscopic fossils from the Danian formations of the Soviet Far East and North America.

At present about 50 families representing 88 genera and 150 species of angiospermous gymnospermous, and spore plants are known. These comprise the flora complex of the formations of the Zeysko-Bureinskaya depression and were uncovered and identified by various investigators from 1914 through 1956. This, however, does not exhaust the flora since many of the plant fossils uncovered remain unidentified.

These genera and species of plants are met irregularly in various flora-bearing horizons of the sequences. A curious regularity is noted in the relationship between certain groups of genera characteristic of stratigraphically dissimilar horizons.

Almost all the genera present in the fossil flora of the Zeysko-Bureinskaya depression exist on the earth's surface today. However, the areals of their distribution are different and in many cases considerably far removed from where they were found as fossils.

The time when any broad group of genera ceased to exist in a given area must be associated with a group of significant changes in the geologic and physicogeographic regime. These changes must have caused the radical reorganization of flora life. It is therefore impossible to ignore the stratigraphic significance of the boundary changes of the regions in which the reorganization took place.

All the flora identified as to system can be broken down into the following groups according to the geographic location of the areals of the genera to which they belong.

I. Group of Holarctic genera (chiefly deciduous, temperate flora).

II. Group of Holarctic-paleo-neotropic genera (chiefly subtropic and mixed subtropic-temperate).

III. Group of paleo-neotropic and Australian genera (subtropical and tropical flora).

These major groups have subgroups arranged according to the geographic classification of their present-day areals (fig. 5).

Using this grouping of genera present as fossilized Cretaceous-Paleogene flora in the depression, it is possible, naturally, to examine the changes in the composition of the geographical elements along a vertical cross-section. In numerical relationships the changes appear as shown in Fig. 6.

From the factual material presented we see:

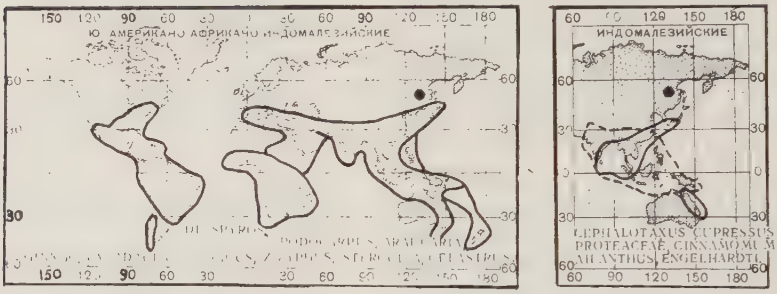
1. Flora from formations connected with the major dinosaur finds, or from formations from the lower horizons of the unconsolidated strata of the Zeysko-Bureinskaya depression marked by genera which today are associated with paleo-neotropic and Chino-Japanese habitats. Chiefly these include: the genera Ficus, Zizyphys, Podocarpus, the families Magnoliaceae, Trochodendroides, Cercidiphyllum, Glyptostropus, Cycadaceae.

At the same time the admixture of the Nolarctic element present in all ancient and more recent flora of the depression is significant. It is characteristic that representatives of Mediterranean, Mediterranean-Chino-Japanese, North American-Chino-Japanese, and North American-Eurasian genera are totally absent. These appear only in flora associated with a cycle of coal accumulation.

It must be noted that these flora bear a remarkable resemblance both to the Lens and Laramie flora of North America, identified now as Danian, as well as to Raton and Denver flora, which on the basis of finds of marine fauna have been identified as Paleocene. This is shown in the data compiled by E. Dorf [22] in his work.

Thus, we conditionally assign flora of the "dinosaur horizon" to the complex of Upper Cretaceous flora, belonging perhaps to the uppermost horizons of the Upper

Paleo-Neotropic and Australian Genera



Paleo-Neotropic, Gravitating to Northern Hemisphere and Holarctic, Gravitating to Southern Hemisphere

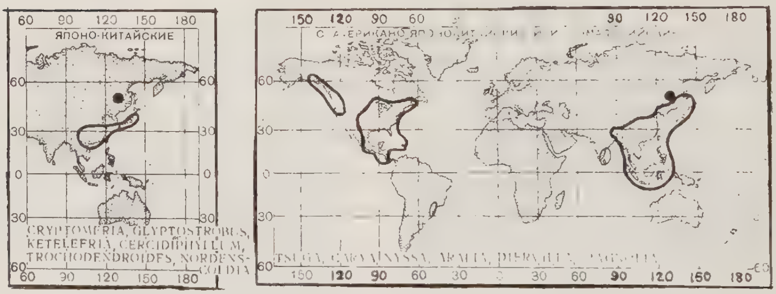
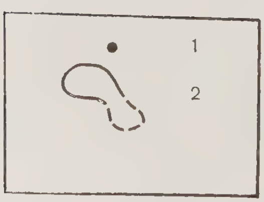


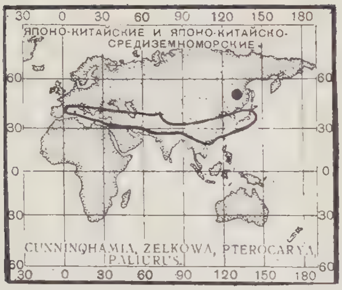
FIGURE 5. Groups of plant genera composing the fossilized flora of the Zeya Bureyan depression, associated on the basis of their contemporary geographic distribution.

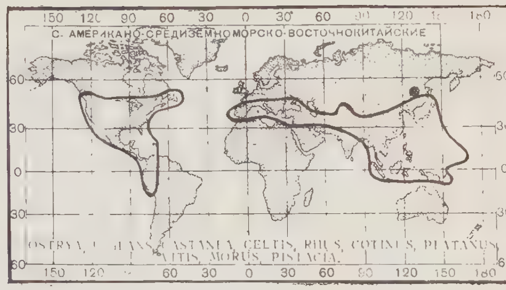


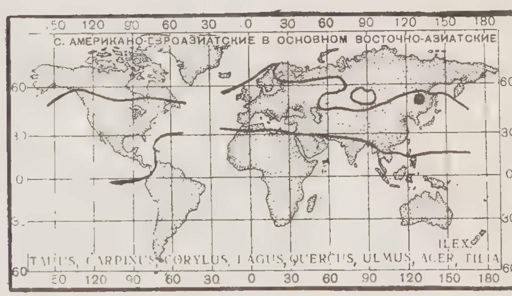
1 - Contemporary geographic distribution of the groups of plant genera.

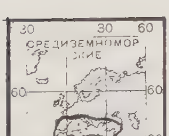
2 - Location of the representative genera of the various groups in the Tertiary and Cretaceous deposits of the Zeya-Bureyan depression.

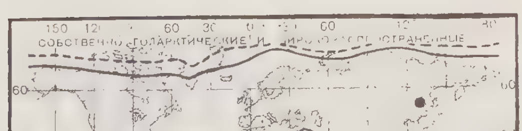
Holarctic and Widespread Genera











Continued from page 34.

TABLE 3. Basic Distribution Scheme for the Principal Locations of Meso-Cenozoic Flora in the Zeya-Bureya Depression

Lithology and Sample Number	Listing of available data on spore-pollen analyses, plant imprints, fauna imprints, with index of location in the cross-sections	
218 216 212 70 Sandy strata with two horizons of lignite	Spore-pollen spectra from clay and lignite layers of the Goryashchiye Mountains Vodorazdel'naya suite, Buzuli (I. Z. Kotova, Ye. D. Zaklinskaya, 1956; Ye. Smirnova, 1936), Soktakhanskaya suite in the Upper Zeya depression	Flora of Goryashchiye Mountains by A. I. Poyarkova [16] and Miocene (?) flora of Abrashikhi (M. O. Borsuk [4])
160 Clayey-sandy strata	Raychikhinskoye brown coal deposit; spore-pollen spectra from clays above the coal (I. Z. Kotova, Ye. D. Zaklinskaya, 1956)	Raychikhi leaf flora (A. N. Krishtofovich [8]; T. N. Baykovskaya [1])
256 257 279 5-meter coal bed	Raychikhinskoye brown coal deposit; spore-pollen spectra from the clay layers within the coal bed (I. Z. Kotova, Ye. D. Zalinskaya, 1956)	Flora from the roof of the coal bed of Shapurkinskoye Deposit (A. N. Krishtofovich, T. N. Baykovskaya, 1941)
137 140 clays	Spore-pollen spectra of clays from the floor of the 5-meter and roof of the 1-meter brown coal beds of the Raychikhinskoye deposit (I. Z. Kotova, Ye. D. Zaklinskaya, 1956)	Raychikhinsk, flora from the clays above the 1-meter bed (T. N. Baykovskaya, 1947)
1-meter brown coal bed	Raychikhinsk, spore-pollen spectra from the clays beneath the 1-meter coal bed (I. Z. Kotova, Ye. D. Zaklinskaya, 1956)	Raychikhinsk, flora from clays beneath the 1-meter bed (T. N. Baykovskaya, 1947)
308 clays		
Sandy-clayey strata with brown coal layers in upper part	Dinosaurs, turtles, estheria of the right bank of the Amur (A. N. Ryabinin [17, 18]; Krishtofovich [7])	Leaf flora from right Amur bank (Krishtofovich [7]) and from Sagibovskiy Boguchan (A. N. Krishtofovich [8])

Old foundation.

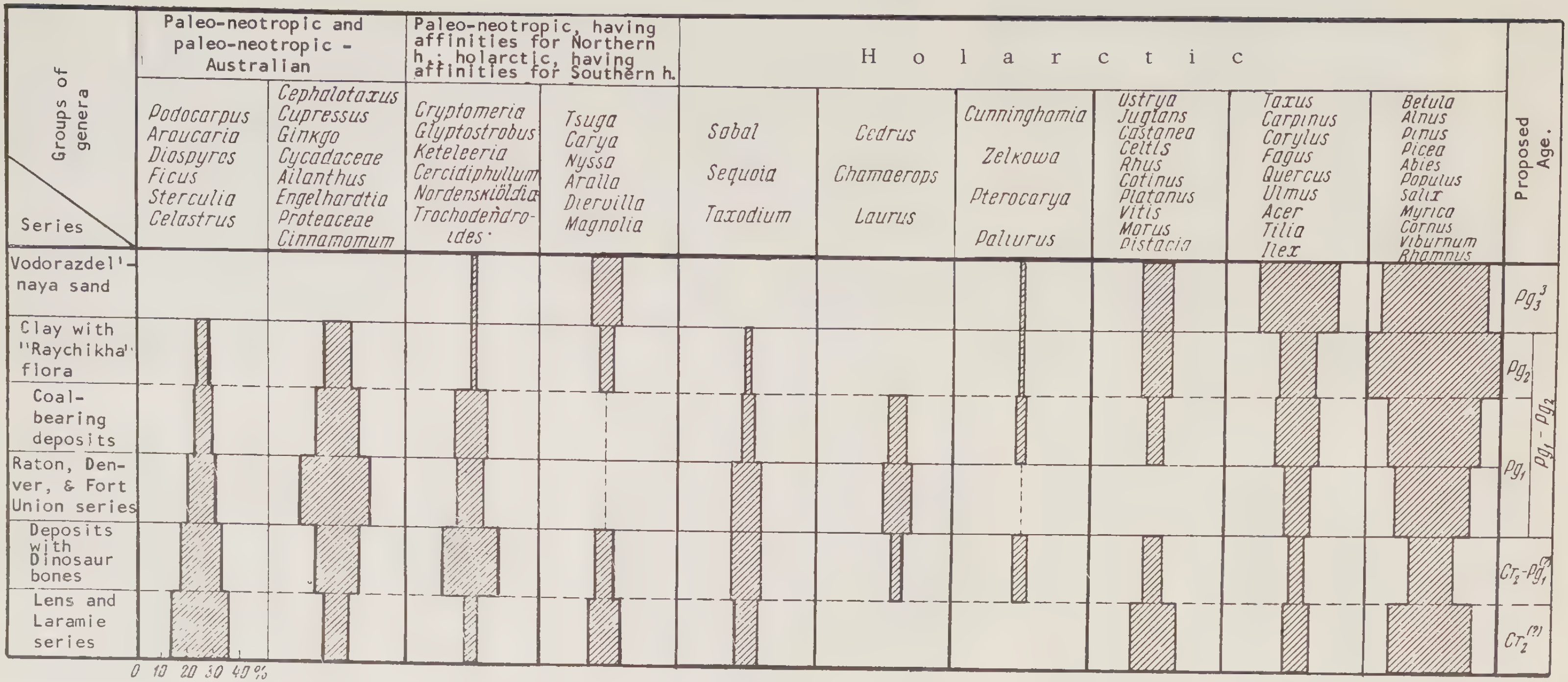


FIGURE 6. A classification of the relation of various groups of genera to their contemporary areas of distribution.

Cretaceous and associated with formations of the Danian stage (?). This flora is distinguished from more recent flora by the great number of species of spore plants and genus Trochodendroides. Its assignment to the Upper Cretaceous is, to a considerable degree, conditional because, in the first place, it, as has been shown above, is extraordinarily close to the Raton flora (Paleocene), and, in the second place, because many of the flora genera, such as Ficus, Trochodendroides, Magnolia, Sequoia, continue to develop intensively much higher, in flora which is definitely identified as Tertiary.

2. A separate flora group identified in horizons associated with formations directly overlying the coal beds of the Kivdo-Raychikhinskoye brown coal deposit, in the coal beds themselves and in the clay layers immediately overlying the coal beds is noticed.

These flora contain almost all the groups of genera enumerated by us earlier. This is especially reflected in the Raychikhi flora, where each group of genera we noted for the Northern and Southern hemisphere is represented by a large number of species.

A group of genera in the flora of the coal beds and from formations immediately overlying them (Raychikhi flora) is not represented so completely. A group of Chino-Japanese genera -- Pterocarya, Zelkowa, Paliurus, and the Mediterranean-North American-East Asiatic Indo-Maylayan group with Castanea, Cotinus, Rhus, Juglans, Vitis, Celtis, and others are absent here. They appear only later.

Genera from the Holarctic group of North American-Eurasian variety, chiefly consisting of representatives of the genera Tilia, Fagus, Acer, Quercus, Taxus, Carpinus, and others appear in the horizon beneath the coal bed, and later attain considerable weight.

The flora identified from formations containing the coal beds and from the clays which overlay the coal beds must be assigned to the Paleocene. The general appearance of this flora differs considerably from the Lens, Laramie, Raton, and Denver group.

Among the Paleocene flora (apparently Paleocene and Lower Eocene) there is flora associated with a time of intensive coal accumulation. This flora was discovered in the clays overlying the coal bed (Raychikhi flora). Characterized by its xerophilic nature, common to all Middle and Upper Eocene flora of the Soviet Union and to the Middle Eocene of Europe, it should occupy a high stratigraphic position (possibly Middle of Upper Eocene).

3. A group of flora from deposits associated with the formations of unconsolidated strata, uncovered in several spots in the Zeysko-Bureinskaya depression and in deposits of the Goryashchiye Mountains, is sharply differentiated. The flora of these horizons is relatively poor in the number of genera which can be assembled on the basis of their present-day geographic distribution. Here paleo- and neotropic genera disappear completely, the Mediterranean element is absent, and the North American Sequoia and Taxodium are either absent or very scarce. First place is occupied solidly by Holarctic and Holantarctic, North American-European-East Asian genera, Alnus, Betula, Carya, Pterocarya, Ulmus, Fagus, and Carpinus. This group of flora is characterized by typically Oligocene plant life in the form of communities of broad-leafed and mixed broadleaf varieties with the deciduous element predominating.

The proposed stratigraphic classification plan for the fossils of the Zeysko-Bureinskaya depression, based on an analysis of the geographic elements, provides the most graphic and solid presentation of the changes occurring in the flora throughout its geologic history. This may serve as a basis for defining the stratigraphic borders for the epochs in which the thick sequences of the unconsolidated formations of the depression were laid down. A stratigraphy which, despite numerous and lengthy investigations of recent years, remains unresolved.

Using floristic data, and taking into account Yavorovskiy's and Muzylev's research as well as petrographic and lithographic data, we propose a new stratigraphic scheme for the unconsolidated formations of the depression (see Fig. 7).

In this plan the formations of the depression are viewed as a single tectonic and lithologic complex composed of continental alluvial formations embracing a relatively long period of time (from the uppermost part of the Cretaceous to the Oligocene, inclusive). In designating the sequences of the unconsolidated formations and the individual suites, we have avoided introducing new names since this would only lead to confusion. Instead we have used common designations. The old names have, however, assumed a new meaning in the new scheme.

We propose the name "Tsagayanskaya Series" to designate the entire group of sequences involved in the unconsolidated formations. We subdivide this into several suites: the Tsagayanskaya, the Kivdinskaya,

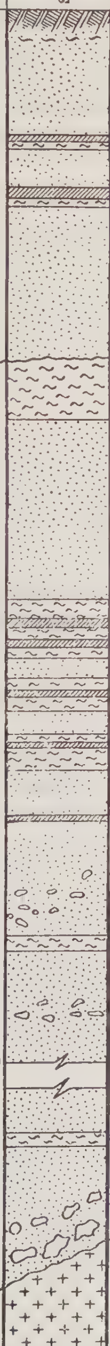
S. A. Muzylev (1948)	Combined stratigraphic column	V. I. Fin'ko and E. D. Zaklinskaia (1957)	Flora
Flat-lying deposits; Neogene sand (Upper Miocene)		Flat-lying friable deposits; Tsagaian series; Watershed sand series; Oligocene	Temperate flora represented primarily by genera distributed at the present time in the holarctic botanic region. Complete absence of mediterranean elements. Vegetation represented primarily by forest communities with a large number of catkin species. Among the conifers there is a relatively large percentage of Tsugu.
Ancient foundations; Tsagaian deposits (Senon-Paleocene); Kivdinian series		Kidvinian series; Paleocene - Eocene	Mixed flora; subtropical with a considerable admixture of temperate species - Populus, Juglans, Alnus, Rhamnus, Viburnum. Wide-spread genera tentatively Paleo- and Neotropical; also some of Indo-Malesian origin. The most widely spread mediterranean genera with Laurus and Cedrus and also species of the Japano-Chinese habitats with Trochodendroides, Magnolia, etc. Many species of Ficus. In the upper beds, a xerophytic flora with Myria Aralia, Phus Proteaceae, etc.
Upper series; Middle series; Lower series		Tsagaian series; Upper Cretaceous	Subtropical flora with a considerable admixture of temperate types. Gymnosperms represented by various species Podocarpus, Sequoia, Glyptostrobus Cunninghamia. A few species of Trochodendroides, Ficus. Angiosperms predominate over gymnosperms. Vegetable remains of peridophytes common.
		Ancient Foundation	Sand Clay Conglomerate Coal and lignite

FIGURE 7. Stratigraphic classification of the unconsolidated formations of the Zeya-Bureya depression (Put together by V. I. Fin'ko and Ye. D. Zaklinskaya).

and the Vodorazdel'naya. Unlike Muzylev's plan our suites have definite time boundaries. Thus, the Tsagayanskaya suite contains only that part of the unconsolidated formations which are marked by Upper Cretaceous fauna and flora. Krishtofovich had proposed this in his studies. At present the upper border of the Tsagayanskaya suite can only be drawn conditionally since the upper boundary of distribution of Upper Cretaceous flora has not yet been established.

It is impossible therefore to draw sharp borders between formations of the Tsagayanskaya and Kivdinskaya suites, since these formations contain gradual transition specimens. But we can identify it in the appearance of the first lower brown coal beds in the unconsolidated sequences.

The coal-bearing strata of the Kivdo-Raychikhinskoye and Arkharo-Boguchanskoye deposits belong to the Kivdinskaya suite. The same is true of the sandy-clayey sequences overlying the coal-bearing beds. These beds are marked by Paleogene flora described by Baykovskaya and Krishtofovich. On the basis of floristic analyses we are inclined to consider the age of this suite as Paleocene-Eocene.

Sequences of unconsolidated formations which are laid down discordantly upon the Kivdinskaya suite as well as all older formations belong to the Vodorazdel'naya suite. The suite's thickness reaches 120 meters.

The Vodorazdel'naya suite is characterized by typical Oligocene flora with a predominance of temperate deciduous varieties. These include flora from the Goryashchiye Mountains described by Poyarkova, and a Miocene complex from the Abrashikh deposits described by Borsuk.

The material presented in this work is by far not exhaustive and the stratigraphic classification scheme, which we consider to be the most reliable, must be further expanded. We consider our method of studying geologic and floristic data the most hopeful in solving the stratigraphic problems when they concern continental formations.

The formations of the Zeysko-Bureinskaya depression are extraordinarily rich in floristic remains and in pollen and spores. Therefore an exhaustive paleofloristic study of this region is absolutely necessary, particularly because the fossil flora is practically the only basis for stratigraphic identification. This is characteristic of all continental formations of the Soviet Far East. In this regard a detailed study of the Zeysko-Bureinskaya depression is of particular interest, since in no other region is it possible to follow such an almost unbroken cross-section of Mesozoic-Cenozoic formations so adequately marked with floristic remains.

Solving the stratigraphy of the depression is of great practical value, since the sequences of unconsolidated formations contain sizeable deposits of kaolin, refractory clay, quartz sand, and brown coal. Furthermore, a more profound paleofloristic investigation is necessary for reconstruction of the most complete and coherent history of Mesozoic and Cenozoic flora and vegetation of southeast Asia.

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Geology of Mineral Deposits, Petrography, Mineralogy, and Geochemistry Institute of the A.S.U.S.S.R.

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A STRATIGRAPHIC SCHEME FOR THE QUATERNARY DEPOSITS OF THE NORTHWESTERN PART OF THE WEST SIBERIAN LOWLANDS AND ITS PALEOFLORISTIC BASIS

by

L. V. Golubeva

ABSTRACT

A paleophytologic basis for stratigraphic subdivision of the Quaternary deposits is presented to aid in determining the number of glaciations, and also for correlation of the different Quaternary stratigraphic units of the northern West Siberian lowlands.

Spore pollen analyses in conjunction with determinations of the macroscopic vegetation remains (seeds and diatoms) show a regular change in the constitution of the vegetation, and, consequently, may be used as the basis for a stratigraphic classification. The changes in vegetation point to a rhythmic oscillation in the climate. Starting from the time of maximum (Samarovian) glaciation, four cool periods alternated with warmer intervals.

* * * * *

The geological investigations carried out recently in the northern part of the West Siberian lowlands by the Geological Institute of the U.S.S.R. Academy of Sciences, the Institute of Geography of the U.S.S.R. Academy of Sciences, the All-Union Geological Institute, the Institute for the Scientific Investigation of the Geology of the Arctic, the Moscow State University, the West-Siberian Geological Administration and other institutes, and the completion of a geological survey (at a scale of 1:1,000,000) and coring work have yielded a vast amount of information on the structure of the Quaternary sedimentary deposits. However, there is still no generally accepted scheme for the stratigraphic subdivision of the Quaternary. Nonetheless, a number of stratigraphic classifications for this region do exist. For a long time, the scheme of V.N. Saks was widely used [12, 13] and in recent years stratigraphic classifications have appeared for the northwestern part of the West Siberian lowlands, compiled by geologists of the All-Union Geological Institute (V.K. Khlebnikov, O.V. Suzdal'skiy et al.), and also the scheme of G.I. Lazukov [9]. There are also schemes for the northeastern part of the West Siberian lowlands by S.A. Arkhipov [1], V.A. Zubakov [5], S.B. Shatskiy [19] and others.

In 1954, S.G. Boch, I.I. Krasnov, S.B. Shatskiy, V.K. Khlebnikov and others compiled the first tentative unified stratigraphic classification of the Quaternary of northern West Siberia. This scheme was accepted by the Council for the compilation of a unified stratigraphic classification for Siberia in January 1956 in Leningrad [17].

As further investigations by a number of geologists have shown, this classification is in need of considerable revision. In this scheme, the Quaternary deposits are divided into four parts: the ancient, middle, recent and contemporary. These divisions are subdivided into stages and strata. Most of the formations and strata have the names given to them by V.N. Saks. However, the stratigraphic units defined in this paleoclimatologic classification do not correspond to the stratigraphic units in all the other geologic classifications based on biostratigraphy.

The terms "division" and "stage" do not fully correspond with the definition given by the "Interdepartmental Stratigraphic Commission" in 1955 [15] and appear to be smaller than the defined taxonomic subdivisions. Besides this, it is necessary to correct the stratigraphic position of the Messian and Sanchugian strata by putting them in a new division, and adding the deposits of the Tazian glaciation to the middle division. Our work, and the investigations of S.A. Archipov [1], V.A. Zubakov [5], and others show that the deposits of the Tazian glacia-

tion, first classified in the eastern part of the West Siberian lowlands by N.A. Naginskiy [10] and later by S.B. Shatskiy, correspond to the Sanchugian stratum (or its upper part) and to the upper part of the Salemalian series in the basin of the lower reaches of the river Ob.

One of the faults of the existing schemes of stratigraphy of the Quaternary deposits is their weak paleontologic basis. For this reason, the correlation of the stratigraphic units of the Quaternary deposits and comparison of local stratigraphic sections of the northern part of the West Siberian lowlands is difficult.

In 1954-55 the authors studied more than 60 profiles (including the profiles of borings) of the Quaternary deposits in the basin of the lower reaches of the Ob. For 30 of the fullest profiles we produced spore-pollen analyses. In all, 420 samples were analyzed from various horizons in the Quaternary deposits. The identification of macroscopic plant remains, seeds, and tree imprints, from post-glacial peat bogs and deposits of the second river terrace was carried out by N. Ya. and S.V. Kats. The diatom flora was studied by A.P. Zhuze and others.

The Quaternary deposits of the northwestern part of the West Siberian lowlands are found almost everywhere and are of considerable thickness. They attain their maximum thickness -- up to 200 m -- in the depressions of pre-Quaternary landforms, which coincide with present valleys and floodplains of the large contemporary rivers. These deposits are thin in the areas between the rivers, and in the vicinity of the Urals, where more ancient rocks lie nearer the surface. The Quaternary formations are distinguished by the variety of their lithologic composition and by their genetic diversity. They are represented by littoral lacustrine, alluvial, glacial, fluvioglacial and aeolian deposits.

The tentative unified stratigraphic classification of the Quaternary deposits, compiled by a group of authors, was corrected by us and changed considerably on the basis of proposals made by V.I. Gromov [4] on the subdivisions of the Quaternary system.

In the classification of V.I. Gromov [4] the Quaternary deposits are divided into three series: Eopleistocene, Pleistocene and Holocene. The Pleistocene is subdivided into three stages: the lower, middle and upper. In the basin of the lower reaches of the Ob the deposits of the Eopleistocene and the lower Pleistocene are either absent or developed to an insignificant degree and are not paleontologically distinct. The most extensive units are the deposits of the middle and upper Pleistocene and the Holocene.

The results of spore-pollen analyses of the Quaternary deposits have shown the possibility of their application in solving stratigraphic questions. However, it is necessary to make auxiliary use of a number of other paleontologic methods, lithology, and geomorphology. The application of the method of spore-pollen analysis, without support of other methods may lead to large errors, especially in studies of the West Siberian lowlands, where, in the Quaternary deposits, there are large quantities of redeposited pollen and spores of Tertiary and Cretaceous plants.

Spore-pollen analyses and also macroscopic study of plant remains, seeds, and diatoms show that in the North of the West Siberian lowlands, during the Quaternary period, changes occurred in the vegetative cover indicating changes in climate -- alternation of "cold" and "warm" phases in the development of the vegetation. The cold phases are characterized by the absence of vegetation or the presence of treeless landscapes; the warm phases are distinguished by climatic conditions close to those obtaining at present but indicating a shift of the tree zone to the north of its present boundary.

Comparative spore-pollen diagrams (figs. 1, 2) complied for the northern part of the region (north of the latitude of the Polar Circle) and for the southern part (south of the latitude of the Polar Circle, between Salekhard and Gorki on the river Ob) show considerable similarity. Besides this, it is evident from the diagrams that from the time of the maximum (Samarian) glaciation four cool periods occurred; the cool periods were interrupted by intervals of warmer climate.

The Quaternary deposits lying stratigraphically below the glacial drift of maximum (Samarian) glaciation are not very thick, not extensive, and paleontologically indistinct. They were discovered by borings of considerable depth -- around 100 to 150 m. In many places, the drift of maximum glaciation lies directly on the Cretaceous rocks and the pre-Samarian deposits are absent. Solitary spore-pollen analyses and the absence of complete profiles of pre-Samarian deposits preclude the establishment of a history for the development of the vegetation during this time interval.

The glacial deposits of the Samarian or maximum glaciation in the region of the lower reaches of the Ob were discovered by borings at a depth of 50 to 150 m. The

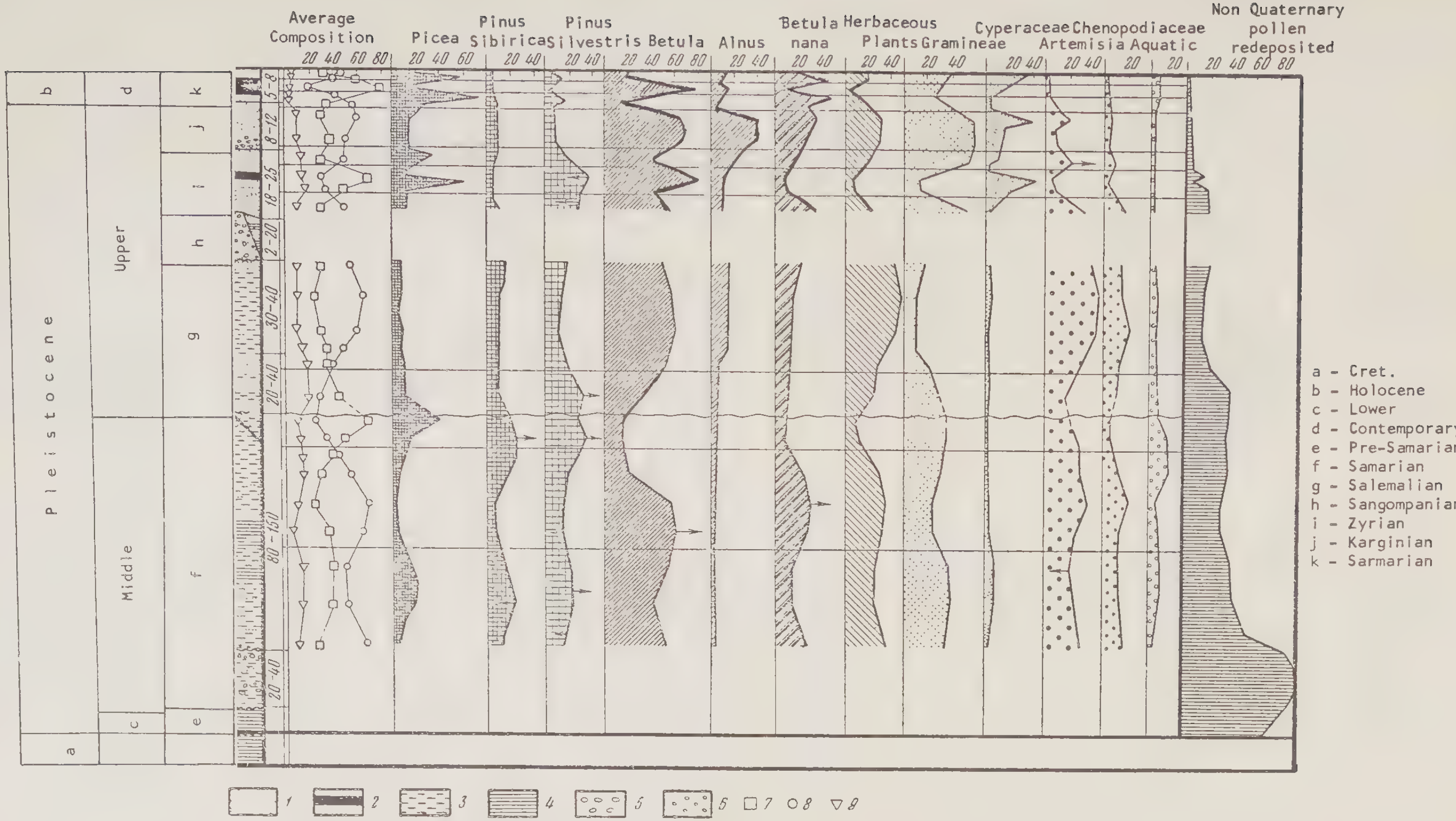

FIGURE 1. Comparative spore-pollen diagrams of Quaternary basin deposits of the lower Ob (north of the Arctic Circle).
1 - Sand; 2 - Peat; 3 - Clayey sand; 4 - Clay; 5 - Boulders; 6 - Gravel; 7 - pollen of tree genera; 8 - Pollen of shrubs, bushes and herbaceous plants; 9 - spores.

The content of spores of Betula nana and of herbaceous plants is calculated in relation to the total number of grains and spores of Quaternary plants.

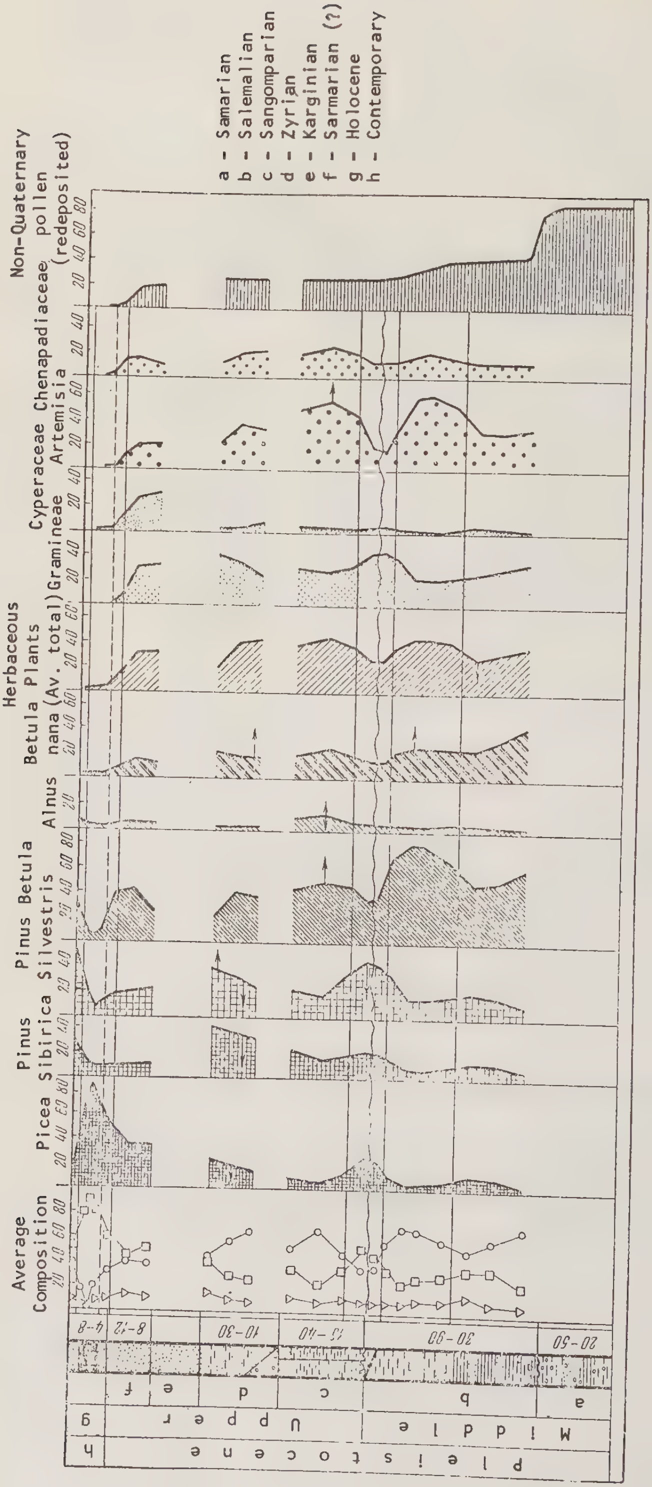

FIGURE 2. Comparative spore-pollen diagrams of Quaternary basin deposits of the lower Ob (south of the Arctic Circle between Salekhard and Gorki)

thickness of the glacial deposits ranges from a few to 50 m, and in some places up to 100 m. The moraine of maximum glaciation is commonly represented by dense boulders of grey or brown-grey mixtures of sand and clay, and more rarely by sandier mixtures and sandstone, clay and sand mixtures with seams of sand. The drift contains a considerable quantity of boulders of Uralian rocks that are oldest in the direction of the Urals.

Spore-pollen analysis of the glacial deposits shows the presence of spore pollen complexes of various ages. Pollens and spores of Cretaceous, Tertiary and Quaternary plants have been identified. A redeposited complex of pollen and spores of Cretaceous and Tertiary age predominates, approximating 80 to 98 percent of all the grains counted.

A large number of spores of Cretaceous plants are present in the drift. Pollen and spores of Quaternary plants are present in small quantity. Solitary pollen grains of conifers, birch, alder, shrubs and herbaceous plants are present, generally poorly preserved; it is possible that they were partly redeposited from older Quaternary deposits. Besides pollen and spores, a large number of redeposited sheets of Upper Cretaceous diatomaceous algae are present.

Lying stratigraphically above the drift of maximum glaciation is a thick layer of sediments, mostly of alluvial origin, which is transgressed by drift of the Zyrian glaciation. The mass is divided into two series, the lower Salemalian and the upper Sangompanian, separated by an erosional surfaces.

The Salemalian series is represented by dense non-stratified and flat-lying, well-stratified clay and sand mixtures, commonly by sand and in places by clay. The commonest lithology is that of the dark grey sand and clay mixtures, but gravel and solitary boulders are also present. The deposition of these sediments took place in land-locked and partly land-locked fresh water basins; the northernmost ones becoming marine.

North of the Polar Circle littoral deposits are predominant, and to the south, lake-lagoon deposits.

The spore-pollen analyses show that Salemalian sediments were deposited during a cold climate in a lake basin, along the banks of which a largely shrubby and herbaceous vegetation had developed. The northern boundary of the tree-zone did not maintain a constant position, at times moving to the north, then receding to the south. At the time of deposition of the lower part of the Salemalian series, 50 to 60 m in thickness, treeless landscapes and landscapes with scattered trees existed.

The pollen of shrubs and herbaceous plants averages approximately 50 percent; trees, 35 to 40 percent; spores, approximately 20 percent; dwarf birches 15 to 20 percent; and herbaceous plants, approximately 30 percent of the total pollen from the Salemalian series. Among the pollen of the herbaceous plants, grass predominates (as much as 40 percent), but some pollen of wormwood, orach, and various other plants is present. The pollen of the aquatic plants (Potamogetonaceae Alismatacea, Sparganiaceae) averages 10 percent. Of the tree pollen, there is much cedar (25 to 30 percent), pine (as much as 30 percent), birch (25 to 60 percent) and Fir (as much as 20 percent).

Solitary pollen grains of larch and fir are occasionally present. This part of the Salemalian Series corresponds to the Messo-Samburgian stratum, as defined by S.A. Arkhipov [1], occurring at the mouth of the Yenisei River.

At the time of formation of the middle, and part of the upper layers of the Salemalian Series (average thickness 50 to 60 m), open landscapes prevailed, and the northern tree boundary moved farther to the south. The spore-pollen spectra indicate that shrubs and herbaceous plants increased to 70 percent and trees decreased to 20 to 25 percent. In the pollen of the herbaceous plants, the amount of pollen of grass, sedges and aquatics decreased, and that of wormwood and orach increased. The pollen of wormwood, according to the determination of M. Kh. Monoszon is represented largely by northern species -- Artimesia borealis L. and A. norvegica Fr. (or A. arctica Less).

Of the tree pollen, the quantity of conifer pollen, particularly fir, is noticeably decreased, and that of birch, predominantly Betula sp., which has features in common with the pollen of both the tree and shrub forms, is sharply increased to 80 to 90 percent. Perhaps these birches were dwarfed northern species.

Similar spore-pollen spectra with an abundance of wormwood, orach and birch are described by R.V. Fedorova [18] and V.P. Grichuk [2, 3] from the glacial deposits associated with the last stages of the recession of the ice sheet. This supports the view that this peculiar xerophytic vegetation, different from the vegetation of the contemporary zone of the tundra, was widely distributed both in the European and in the Asiatic parts of the U.S.S.R.

The cooling which occurred at the time of formation of the middle and, to some extent, of the upper part of the Salemalian Series, apparently, corresponds to the time of the Tazian glaciation, ascribed to the northeastern part of the West Siberian lowlands by S.B. Shatskiy [19] and to the time of formation of the Yeniseian horizon of V.A. Zubakov [5].

The Tazian glaciation did not occur everywhere. In the region of the lower reaches of the Ob, in the West Siberian lowlands, an aquatic basin continued to exist at this time. The question of the independence of the Tazian glaciation is still debatable. The proof is still not convincing; further investigations are needed on this point.

The Paleophytologic material at our disposal, from the lower part of the Salemalian Series, shows that in the interval between the Samarian and Tazian glaciations, in the northeastern part of the West Siberian lowlands, it was considerably colder than at the time of formation of the upper Salemalian and lower Sangompanian series. The northern tree boundary at this time was south of its present position. The spore pollen analyses, carried out by E.V. Korenevaya for the Messov-Samburgian horizon of corresponding age (present in the region of the lower reaches of the Yenisei), also show no evidence for the occurrence of a warm inter-glacial period and indicate rather an inter-stage or cold inter-glacial period.

During the accumulation of the uppermost part of the Salemalian series, 7 to 10 m in thickness, the northern boundary of the forests again moved to the north and, apparently, considerably farther than during the deposition of the lower part of the series. This may have been associated with a warming of the climate, a regression of the Salemalian sea, and the emergence of a large dry territory from under the water. The spore pollen spectra from the upper part of the series is characterized by a predominance of tree pollen having a considerably larger quantity of conifer spores, especially fir (as much as 40 percent) and a smaller quantity of birch spores in places only 10 to 15 percent. There is a large reduction also in pollen of shrubs and herbaceous plants. It is possible that at this time the forests extended north of their present boundary.

The warm phase in the development of the vegetation, beginning at the end of the Salemalian period and affecting arboreal conditions continued into the Sangompanian period. This stage in the development of the vegetation coincides with marine regression and the removal by erosion of the top of the Salemalian deposits.

In the southern part of the region, the top part of the Salemalian series, representing the warm period, is considerably eroded, and on the spore-pollen diagram (fig. 2) the forest-phase is less characteristically developed than in the north part of the region.

According to the determinations of A.P. Zhuze, the diatom flora in the deposits of the Salemalian series is represented by solitary forms characteristic of fresh-water lake basins. Stauroneis phoenicenteron, Ehr, Amphora ovalis Kutz, Tabellaria penestrata (Lyngb) Kutz, etc., are present. Large numbers of redeposited paleogenic marine forms are also present.

The Sangompanian series is represented along the northern borders of the region by littoral sediments and in the south by continental lacustrine sediments and lacustro-alluvial deposits. These deposits generally lie on the eroded surface of deposits of the Salemalian series and have their greatest thickness in areas of low relief.

In the region of the latitudinal segment of the river Ob and to the north, the deposits of the Sangompanian series are transgressed by glacial drift of the Zyrian glaciation, and to the south by lacustro-glacial, fluvio-glacial, and lacustro-alluvial deposits.

The spore-pollen analyses (figs. 1, 2) show that at the time of deposition of the lower, predominantly sandy, stratum of the Sangompanian series, the climatic conditions in the north and the south were close to those present today; and at times, the tree vegetation moved north of its present boundary. In the spore-pollen spectra of this region, tree pollen generally predominates; pollen of conifers, especially pine and fir, is most abundant. Grasses are most commonly represented in the pollen of the herbaceous plants, but a large quantity of wormwood and orach pollen is also present. Besides this, many spores of sphagnum moss and pteridophytes are present.

V.N. Sukachev [16] discovered vegetable remains of Menyanthes trifoliata L, Carex rostrata Stock, etc., in the lower part of the sand and clay masses at Sangompan. At the present time, these species occupy an area south of that in which their fossil remains are found.

At the time of accumulation of the upper, largely clayey, and thicker part of the Sangompanian series, the climate was becoming cooler. Even in the southern part of the region, covered at the present time by north Taiga forests, treeless landscapes

existed.

The pollen of shrubs and herbaceous plants dominates the spore-pollen spectra of these deposits. Among the trees represented, there is a considerable reduction in the content of conifer pollen, and there is an increase in that of Betula and Alnus. Among the pollen of the herbaceous plants, wormwood is increased to 50 to 60 percent and orach to 25 percent. In relation to the total number of pollen grains and spores of the Quaternary plants, the quantity of pollen of wormwood is 20 to 35 percent and of orach 10 to 20 percent.

The diatom flora is distinguished by considerable diversity and consists largely of forms characteristic of standing fresh water lake basins, and more rarely of flowing water. The most extensive are the genera Eunotia, Navicula, Pinnularia, Gymbella, and others, represented by a few species. Marine forms, Bacterosira fragilis (spores) Grammafophora arcuata Ehr. and others, are present only along the northern borders of the region.

Glacial deposits of the Zyrian glaciation are distributed mostly in the northern part of the region. The Zyrian glacial drift is distinguished from the Samarian by the presence of a large quantity of sandstone fragments and many pebbles and boulders. that consist largely of rocks of the eastern slope of the polar Urals. Pollen and spores in the glacial deposits of the Zyrian glaciation are exceedingly sparse. Only rarely have solitary pollen grains been found and even these are in a poor state of preservation. In distinction from the drift of maximum glaciation, with the exception of solitary grains, no redeposited spores and pollen of Tertiary and Mesozoic plants are present.

The later glacial deposits are most extensive south of the region where glacial drift occurs. According to V.K. Khlebnikov these deposits form a wide, low, morphologically distinct plain along the right bank of the Ob -- to the south of its latitudinal segment. Maximum relief on this plain is 45 to 50 m. Below the unconsolidated materials of this plain lie Sangompanian and even older rocks. The deposits of late glacial basins are represented by persistent seams of fine-grained sand and clayey sand, more rarely by sandy clay and clays.

In the spore pollen spectra of these deposits (fig. 2) the pollen of herbaceous plants is predominant, but large amounts of pollen from shrubs are also present. Grasses, wormwood, orach and diverse grassy plants are well represented in the pollen of the herbaceous plants.

The diatom flora is represented by forms characteristic of fresh, cold-water basins -- Navicula amphibola, C. L. Cymbella aspera (Ehr.), Eunotia praerupta, (Ehr.), etc.

The data from spore-pollen analyses, the character of the diatom flora, the lithologic structure and texture of the sediments all lead to the conclusion that the deposition of the laminated mass of sand and clayey sand took place in a wide, shallow, fresh-water basin, under low temperatures, or most likely in a group of such basins. The existence of this lake basin coincided with the time of advance of the Zyrian ice sheet.

The second river terrace is most widely developed in the region of the latitudinal segment of the Ob and is described for the villages of Panayevsk, Yartsinga, Aksarka, and other places. Its height above water level ranges from 15 to 24 m. The terrace consists of well assorted fine-grained and medium-grained sand with flat-lying and inclined beds, with their gravel seams, and also sandy clay and clayey sand beds with seams of peat.

The spore pollen analyses show a change in the vegetation at the time of accumulation of the material of the second river terrace. The lowest beds of the terrace deposits probably were formed at the time of the advance of the Zyrian ice sheet and correspond, in part, to the lacustro-glacial and lacustro-alluvial deposits of the late glacial period. The spore-pollen spectra of the lower beds are characterized by pollen predominantly from shrubs and herbaceous plants.

The deposition of the middle part of the lacustro-alluvial deposits of the terrace took place in considerably warmer climatic conditions. The spore-pollen spectra of these deposits is distinguished by the predominance of the spores of trees, of which a considerable proportion is made up of the pollen of fir, forming the lower and upper maxima, and much birch pollen, but the pollen of larch is also present. The structure of the spore-pollen spectra and the finding of imprints of fir, larch and birch in the zone of the present tundra gives evidence of the former existence of forests north of their present position. This period probably coincides with the maximum of the Karginian transgression described by V.N. Saks [12] for north Siberia.

During the formation of the upper strata of the second river terrace, the climate again began to cool. The spore-pollen analyses indicate an increase in the pollen of

shrubs and herbaceous plants and a decrease in the quantity of conifer pollen, especially fir. The northern border of the forest zone again receded southward.

The first river terrace is quite extensive in the valley of the Ob and its tributaries. In the northern part of the region (fig. 1) the spore-pollen spectra indicate that pollen of shrubs, bushes and herbaceous plants predominate. The content of pollen of Betula nana reaches 40 percent, Ericales 11 percent. Among the pollen of herbaceous plants, grasses, sedges, and grass plants are represented; among the tree pollen there is a preponderance of pollen from birch and alder. In the southern part of the region (fig. 2), the spore-pollen spectra show a small predominance of tree pollen -- birch and fir, and some larch. The pollen of the herbaceous plants, forming on the average about 30 percent, contains the pollen of grasses, sedges, wormwood and grass plants.

The paleophytologic material shows that the deposition of the alluvial and lacustrine sediments of the first river terrace took place in the northern part of the region in tundra, and in the south part in forest-tundra landscapes.

According to the majority of investigators, the period of accumulation of alluvium of the first river terrace coincides with the period of the mountain-valley Sartanian glaciation. Some workers (V.A. Zubkov and others) relate the Sartanian glaciation to the third, and last, stage of the Zyrian glaciation. V.N. Saks and S.G. Boch, and many others consider the Sartanian glaciation to be independent. From our data, the Sartanian glaciation, although of small extent, was separated from the Zyrian glaciation by the interval during which the sedimentary beds of the second river terrace were deposited, when the climatic conditions were warmer than at present and forests covered an area considerably north of their present northern boundary. The Sartanian ice sheet apparently did not extend itself beyond the foothills of the Urals. In the lowlands, only fluvioglacial deposits of this glaciation are present. The cutting of the first terrace probably took place at the conclusion of the Sartanian glaciation or later.

The Holocene is represented by lake and march, alluvial, and aeolian deposits. The alluvial deposits form a high and low flood plain; the lake and marsh deposits consist mostly of peat. The peat accumulations occupy a considerable area and in parts cover the alluvial deposits of the river flood plain, of the river terrace, and of the interfluvial uplands where they form hills up to 5 m in height.

The structure of the peat and its degree of decomposition are varied. The most widely distributed types are the sphagnum and sedge-sphagnum peats. It is not uncommon to find the shrub-sphagnum type, filled with the remains of dwarf birch; arboreal peat is also present.

The rich paleobotanical material in the Holocene peat bogs of north West Siberia was obtained from the work of V.N. Sukachev [16] and N. Ya. Kats and S.V. Kats [6-8].

By considering all the data of the spore-pollen and other paleobotanical analyses it is possible to draw the conclusion that in the Holocene there were three phases of development of vegetation. At the time of accumulation of the sand or clayey sand, underlying the peat, and of the lowest layers of peat in some places, the climatic conditions were cold-temperate and close to those of the present. In the north, the spore-pollen spectra of this part of the profile indicate a predominance of shrubs and herbaceous plants. Betula nana pollen averages 50 percent of the total for all the grains. Among the tree pollen fir is in the majority (as much as 80 percent), forming the lower maximum. Solitary pollen grains of larch have been reported. The sediments were deposited in a fir-larch forest tundra having a considerable amount of dwarf birch in the vegetative cover. In the southern part of the region, it is possible that there existed a birch-fir landscape of scattered trees.

The accumulation of most of the peat took place during the time of a warm climatic optimum. Trees grew considerably north of their present northern limit and other boreal forest and marsh species existed with them. Birch pollen (Betula pubescens and other species) is most abundant, followed by fir. In the peat bogs of the now treeless tundra the remains of fully mature birch have been discovered (bark, stems), larch (bark, needles), fir (needles, cones), and also Carex rostrata Stok, Cares vesicaria L, Menyanthes trifoliata L) and other plants, forming the basic components of the peat in many places.

Spore-pollen analyses of the peat bogs of the southern part of the region are characterized by a preponderance of fir pollen and more rarely of birch.

At the time of accumulation of the lowest peat layers the climate was becoming colder, approaching that of the present. From the northern marshes the boreal species disappeared and the tundral forms Aulacomnium

turgidum (Whlg.) Sch., Dicranum elongatum Sch., Carex chordorrhize Rhr, Batula nana, etc., took their place.

The forests receded southward to their present position. Spore-pollen analyses of this horizon indicate an increase in shrubs and herbaceous plants. The quantity of Betula nana pollen again reaches 40 to 50 percent and forms the upper maximum.

Comparing the data obtained with the scheme of division of the Holocene by M.I. Neystadt [11], it is possible to conclude that the first phase in the development of the vegetation corresponds to the early Holocene; the second (warm) phase corresponds to the middle Holocene; and the third phase corresponds to the late Holocene.

Thus, the data from spore-pollen analyses, supported by determination of macroscopic plant remains, seeds, and diatom flora provide valuable paleofloristic data suitable for stratigraphic correlation. They show a regular change in the structure of the vegetation in the north of the West Siberian lowlands and can be used as a basis for stratigraphic classification of the region.

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Geological Institute, Academy of Sciences of the S.S.S.R., Moscow

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THE PATTERN OF DISTRIBUTION OF IRON ORE DEPOSITS IN THE SAKSAGANIAN REGION OF KRIVOY ROG

by

A. T. Dzhedzalov

ABSTRACT

The conditions of formation of the ancient weathered zone in the Saksaganian belt of Krivoy Rog are elucidated. A basis has been found for correlating the rich ore beds with fracture zones. The general pattern of weathering of the ferruginous quartzite and pattern of ore formation are examined.

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INTRODUCTION

In the general distribution of the iron-bearing deposits of Krivoy Rog (defined as deposits suitable for ore extraction) the ore formations of northern Saksaganian and the southern region are distinguished by mineralogical composition, structural and textural properties, by their restriction to definite types of tectonic structures and by their spatial relations with one or another type of metamorphic rock. They are also distinguished by the distinct character and degree of development in the beds containing ore, of textures resulting from post-magmatic processes, and by a number of other criteria.

The various ore-bearing formations have different origins and their development took place in different periods and under different geological conditions. This is indicated by their isolation from one another and by the absence of ore-bearing formations of a transitional type.

All the iron-ore deposits of the northern region are in contact with recent red, microclinic granites. There is no doubt as to the paragenetic relation of the iron ore-bearing beds with these granites.

The formation of part of the ore beds of the southern region, and in particular of the amphibole-magnetic and chlorite-magnetic ores is apparently related to the grey microcline-oligoclase granites which are widely distributed along the western border of the Krivoy Rog metamorphic belt. Several investigators relate the formation of the martite ores to the processes taking place in the weathered zone. The question of the supergene origin of these ores has been fundamentally studied in the works of L.I. Martynenko [6], D.S. Korzhinskiy [4], M.N. Dobrokhotov [2], V.N. Kotlyar [5], and many others. However, the geologists of the Geological Exploratory Trust are still guided by the old hypothesis of the endogenic origin of the rich ores of the Saksaganian belt.

Among all the geologic factors influencing the development of the ancient weathered zone and the distribution of ore beds, the most important fundamental factors are the lithologic composition of the rocks and the disjunctive tectonic structures, formed before the epoch of ancient erosion. However, up to the present time these important factors have not been sufficiently described in the literature.

In the present article, an attempt has been made to elucidate: 1) the conditions of formation of the ancient weathered zone in the Saksagan region of Krivoy Rog, 2) the relation of the ore-bearing beds to the distribution of fractures, and 3) the general pattern of spatial distribution of areas affected by those weathering processes controlling the genesis of iron ore-bearing beds.

SHORT NOTES ON THE GEOLOGIC STRUCTURE OF THE SAKSAGANIAN BELT

The Saksaganian belt, representing the

eastern limb of the Krivoy Rog synclinorium is divided into two parts having sharply distinct structures: 1) the southern part, stretching from the Dzerzhinskiy mine to the Frunze mine, and 2) the northern part, stretching from the Frunze mine to the "Pervoye Maya" mine.

In the southern part of the region the metamorphic rocks of the Krivoy Rog series form an isoclinal fold -- the Saksaganian syncline and the Saksaganian anticline. At the point of juncture of the synclinal and anticlinal folds this structure is broken by a longitudinal thrust in which the anticlinal part is thrust over the synclinal.

Hence, the portion of the Saksaganian belt under review is a folded structure, formed at the overthrust by the juncture of the eastern limb and the trough of the syncline with the undamaged western limb of the anticline.

The Saksaganian syncline and the Saksaganian anticline are inclined to the east over the whole region. Their axial surfaces have a wavy form and a steep dip (50° to 70°) to the west. The axes of the folds are inclined to the north at an angle of 12° to 18°. In the area between the exposure of the axial trace of the folds on the weathered surface and the northern boundary of the Artem mine, the Saksaganian belt plunges to a depth of about 1,000 to 1,500 m; in the region of the northern border of the area, the depth of the folded structures apparently reaches 2.0 to 2.5 km. The Saksaganian isoclinal folded structure does not spread north of the Frunge mine. The northern part of the Saksaganian belt represents the normal eastern limb of the original Krivoy Rog syncline.

The folded structures of the Saksaganian belt are complicated by fractures. An exceptionally important role in the development of the geological structure of the region, in the formation of the weathered zone, and in the formation of ore-bearing beds is played by the large longitudinal, diagonal and transverse faults accompanied by smaller ruptures.

ON THE CONDITIONS OF FORMATION OF THE ANCIENT WEATHERED ZONE IN THE SAKSAGANIAN REGION OF KRIVOY ROG

The territory of the Krovoy Rog metamorphic belt was an area of drought and denudation, apparently over a prolonged period, from the Upper Proterozoic to the Tertiary. The rocks of Precambrian formations forming mountainous areas above the local and regional base level were subjected to intense erosion; because the friable products of chemical and mechanical disintegration were not protected from subsequent erosion and were quickly washed away a surficial weathered zone, similar to that which was built up in the region of the Kursk magnetic anomaly, could not be preserved.

The ancient weathered zone in the Saksaganian region of Krivoy Rog is best developed along fractures. Observations show that it did not develop everywhere but in separate localities having distinctly different structural conditions, and that it is spatially connected with fracture zones in the weakly metamorphosed ferruginous quartzite, untouched or only lightly touched by post-magmatic metasomatic processes.

The absence of a weathered zone of the Saksaganian type in the northern region of Krivoy Rog is explained, apparently, by the fact that here, in an area of intensive development of metamorphic and metasomatic processes, i.e., in a zone of intensive action on the mass of rocks by rising solutions, the clefts and voids formed in the rocks during periods of deformation were filled up. Because of this, meteoric water had no access to the iron-bearing layers; consequently zones of oxidation and leaching along fissures and fractures did not develop. In the southern region of Krivoy Rog, as a result of less intensive endogenic post-magmatic processes, the fissures that formed at the same time as the folding, in some regions apparently remained open, or were opened a second time during the period of tectonic activity which produced the northern ore deposit. Hence, beds of rich ores of the Saksaganian type were formed.

It should be noted that in the formation of a surficial weathered zone, oxidation extends itself downward through the porous material and fine cracks, and the processes of weathering proceed more or less evenly through the whole mass of rocks. During development of a weathered zone, leaching proceeds along the cracks right at surface level and at a considerable depth, to which the oxygen-rich surface water quickly penetrates. Hence, very commonly, blocks of almost unaltered rocks occur in the topmost parts of the deep zone of oxidation.

Almost all the rocks of the metamorphic belt of Krivoy Rog are affected by recent or Meso-Cenozoic weathering. In the northern and southern regions the depth of the oxidation zone in the ferruginous quartzite varies from 10 to 60 m. In the Saksaganian region, a zone of recent weathering is superposed on the ancient weathered zone and is being

developed in the intermediate layers between them. Here the zone of oxidation is considerably deeper, and in some regions reaches a depth of 150 to 350 m. It is characteristic that the weathering agents penetrate most deeply in the mass of jaspilite of the 5th iron-bearing stratum.

In the upper levels of the comtemporary oxidation zone the weathering processes affecting the ferriginous quartzite show themselves for the most part in the oxidation of iron silicates, carbonates and magnetite, and also in the removal of alkalies, alkaline earths and iron. In the lower part of the zone of oxidation, surface water apparently dissolved and removed silica. This is borne out by the fact that the SiO_2 content in the mine water reaches 15 to 20 mg liter.

The development of the ancient weathered zone and the formation of ore deposits in the Krivoy Rog region took place after the cessation of all endogenic magmatic and metamorphic processes. The following facts tend to support such a conclusion.

1. Some extensive martite ore deposits taper out at a depth of 350 to 500 m from the surface and change to unoxidized magnetite-ferruginous quartzite. To such beds belong the Klubnaya, the Yuzhnaya Ventilyatsionnaya, and the Lenin mine of the 1st Saksaganian bed; the Klubnaya Krasnaya Guardiya mine; the Tsibul'ka Parts'ezda mine; the Yuzhnaya and Bol'shevik No. 5 mine and others. The transition from oxidized martite to unoxidized magnetite-quartzite is gradual. In places, the lower boundary of the transition is very irregular, in the form of a pocket (see fig. 1).

2. The semi-friable ores and rocks of the Saksaganian belt show no traces of tectonic influence. Up to the present no tectonic activity subsequent to the ore formation has been detected in the Saksaganian region. The statement of Ya. N. Belevtsev that in the Saksaganian region major disruptions usually appear to have taken place after the formation of the ore is not borne out in fact. It is necessary to emphasize that Ya. N. Belevtsev offers no proof in support of his point of view on the post-ore age of these disturbances.

The major disruptions in the Saksaganian belt are established as earlier than ore formation on the basis of the following observations.

(a) No mixing of the bodies along the intersecting fracture zone is observed. The slickensides, "clays of friction" and other "signs of movement" within the ore bodies and near the contacts with the enclosing rocks appear to be older than the ore bodies because the ores themselves show no signs of tectonic disruption, and narrow ore protrusions penetrate into the host rocks and intersect the zones of joints.

(b) The large fractures and the finer fractures connecting them form ore bodies in some locations (see figs. 2, 3, 4, 5).

(c) The ore-bearing longitudinal and diagonal fractures are intersected and displaced by transverse fractures filled with diabase dikes which were injected before development of the ore bodies (see fig. 3).

(d) The surfaces of tectonic ruptures were involved in the settlement folds, arising in the process of ore formation, as a result of gravitational contortion of the rocks (see fig. 5).

3. The fine folds in and near the ore bodies, which N.P. Semenenko considers to be plastic drag folds, and which he attempted to use in the interpretation of regional structures, have in our opinion a different origin, namely gravitational folding.

This folding, superposed on the large continuous settlement folds, is distinguished by its localization in a separate layer (or group of layers) included between the undeformed layers. Owing to friction, the lower part of the subsided plastic layer is less crumpled than the upper part, i.e., the folding is most intensively developed in the upper part of the deformed layer. This unusual micro-folding, which is strikingly different from normal folding resulting from tectonic strain, has an irregular appearance. It could have arisen only as a result of the settlement of plastic, laminar, ferruginous quartzite impregnated with water.

4. It has been established by detailed structural and petrographic mapping that the zones of alkaline metasomatism, developed among the oxidized and impregnated ferruginous quartzite, are everywhere dislocated concordantly with the altered rocks. They and the oxidized rocks are equally present in the folds penetrated, by a single network of fractures that similarly affected the altered rocks. In some localities they are completely oxidized and leached.

5. No signs are found of the influence of metamorphic or hydrothermal processes in the weathered zone of the Saksaganian belt.

6. Study of the relative ages of the ore beds and diabase dikes intersecting the folded formations of the Saksaganian belt at right angles to their strike, has shown

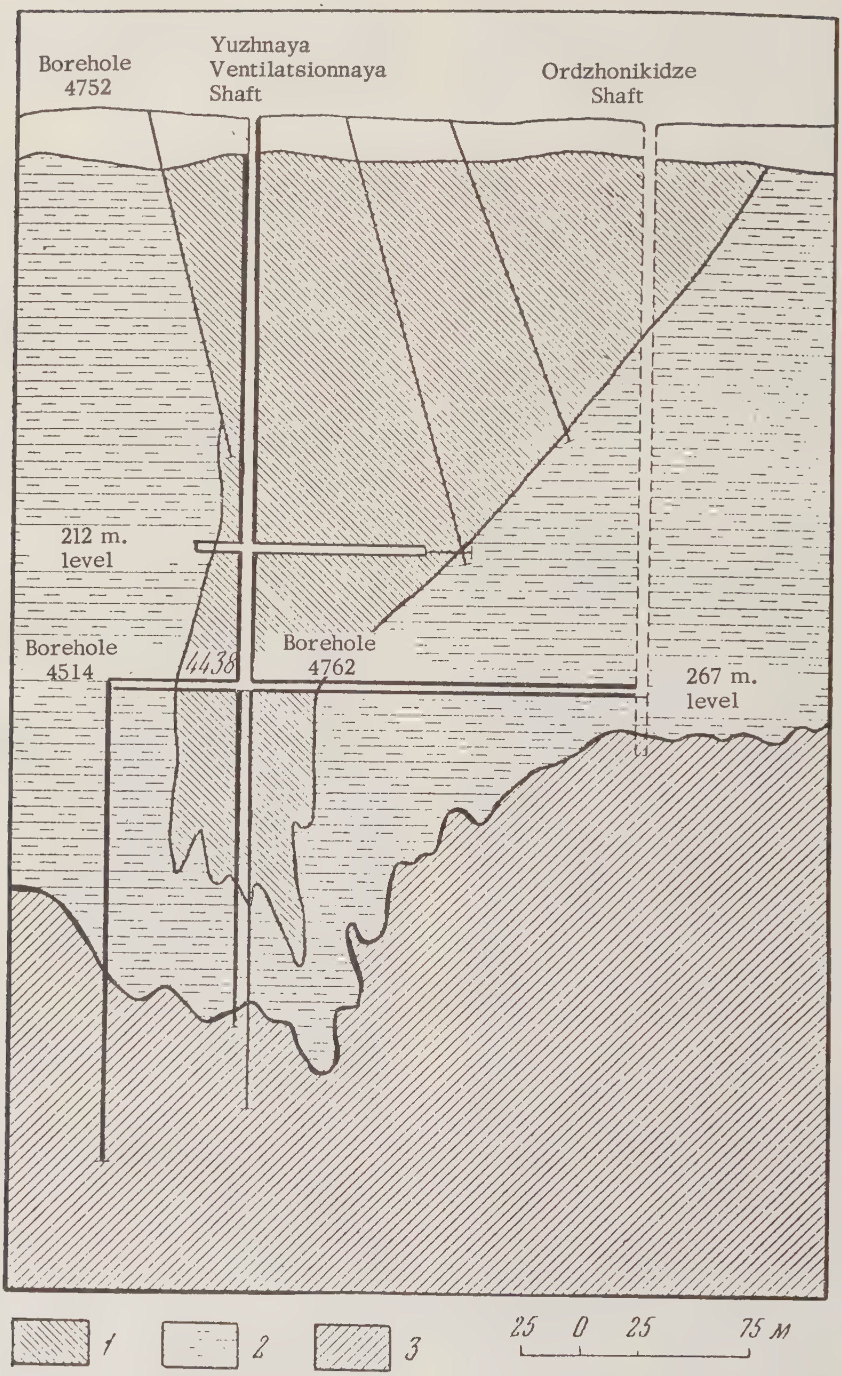


FIGURE 1. Vertical projection of the Yuzhnaya Ventilyatsionnaya ore deposit, Lenin mine.

1 - Martite ore; 2 - Oxidized ferruginous quartites; 3 - Unoxidized magnetite - ferruginous quartzites.

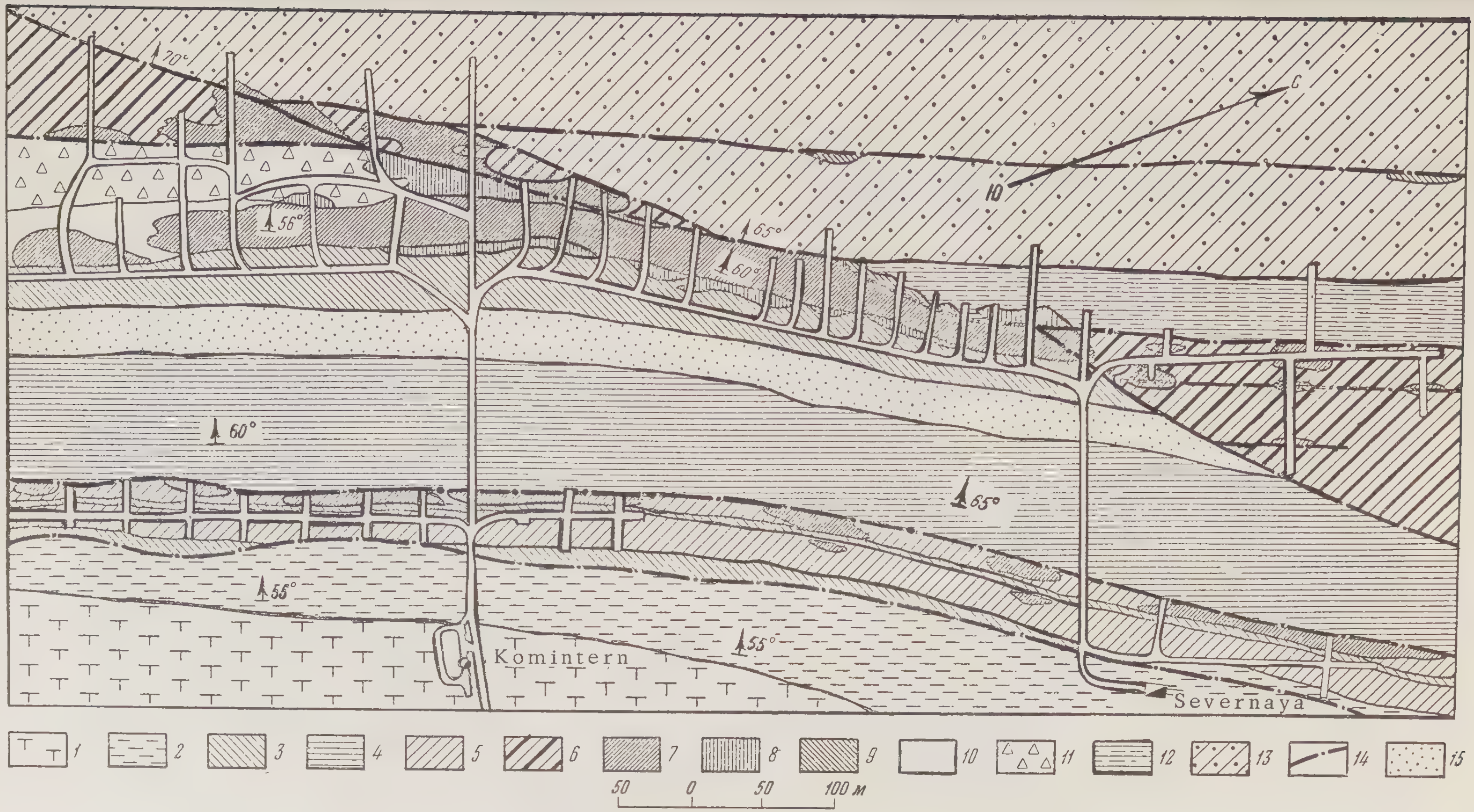


FIGURE 2. Geologic Plan of the 367 m level of the Komintern shaft.

1 - Phyllite; 2 - Talc schist; 3 - Chlorite and hydrohematite schist; 4 - Hydrohematite schist and oreless quartzite; 5 - Martite quartzite of the 1st and 2nd iron-bearing layers; 6 - Martite quartzite of the 6th iron-bearing layer; 7 - Martite ore; 8 - Hydrohematite ore; 9 - Hydrohematite martite ore; 10 - Jaspilites; 11 - Schist and hydrohematite ore with martite crystals; 12 - Chlorite and hydrohematite schist; 13 - Silicate - ferruginous quartzite; 14 - Zones of tectonic disturbance; 15 - Schist and oreless quartzite with subsidiary seams of ferruginous quartzite.

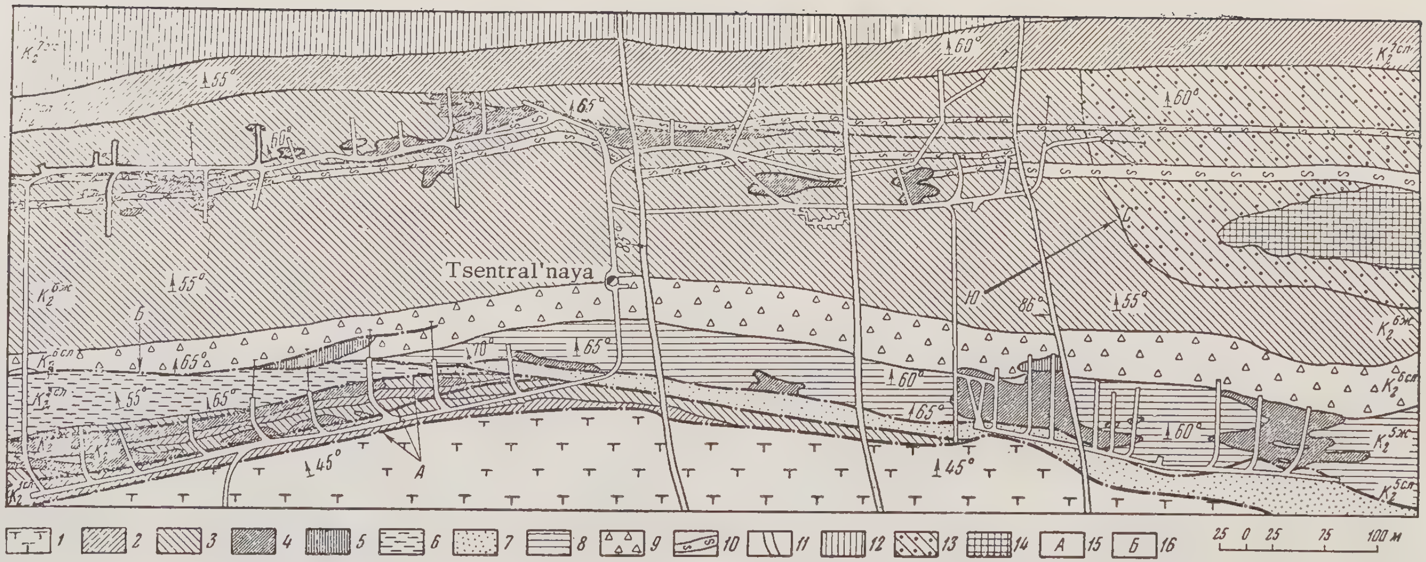


FIGURE 3. Geologic plan of the 186 m Tsentral'nya shaft of the Frunze mine.

1 - Talc schist; 2 - Chlorite and hydrohematite schist; 3 - Martite quartzite; 4 - Martite ore; 5 - Hydrohematite ores; 6 - Chlorite schist; 7 - Hydrohematite quartzite; 8 - Jaspilite; 9 - Schist and hydrohematite ores with martite crystals; 10 - Hydrohematite quartzite and schist; 11 - Diabase dikes; 12 - Hydrohematite and martite quartzite; 13 - Martite-magnetite quartzite; 14 - Zones of alkaline metasomatism; 15 - The Eastern underthrust fault zone (the fundamental tectonic joint extending along the contact of the chlorite and talc schist); 16 - Zone of the diagonal reverse thrust fault.

FIGURE 4. The geologic plan of the 200 m level of the Tsentral'naya shaft, XX Parts'yezda mine.

1 - Chlorite schist; 2 - Hydrohematite quartzite with martite crystals;
5 - Martite quartzite; 6 - Martite ore; 7 - Zones of tectonic disturbance.

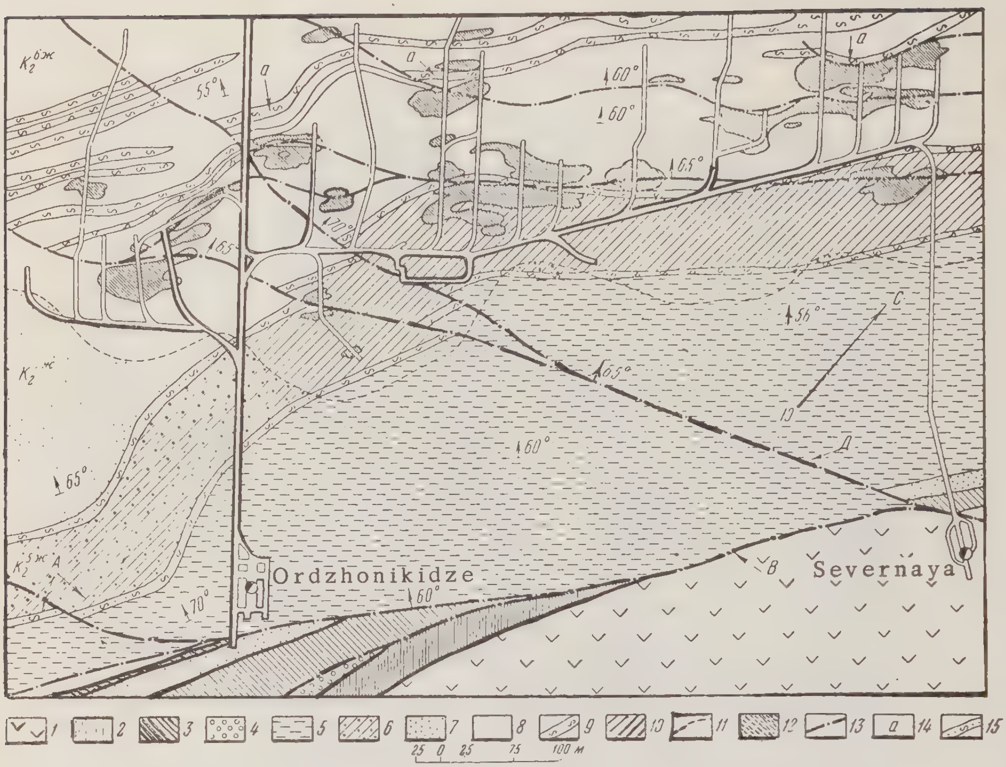


FIGURE 5. Geologic plan of the 447 m level of the Ordzhonikidze shaft.

1 - Arkose; 2 - Phyllites; 3 - Chlorite schist; 4 - Talc schist; 5 - Chlorite-biotite and biotite-sericite and hydrohematite quartzite; 6 - Magnetite jaspilite; 7 - Magnetite hornstone; 8 - Martite hornstones and jaspilite; 9 - Hydrohematite quartzite; 10 - Martite jaspilite; 11 - Eastern contour of the ancient weathered zone; 12 - Martite ore; 13 - Zones of tectonic disturbance; 14 - Settlement (subsidena) fold; 15 - Magnetite and silicate-ferruginous quartzite: B - Vostochnaya underthrust, D - main diagonal fault, A - Location of the pinching-out Yuzhnaya Ventilyatsionnaya deposit.

that the ore bodies are commonly developed only from one side of the diabase dikes (see Fig. 2); in other cases, the profiles of the ore beds on the two sides of the diabase dikes do not correspond (see Fig. 3). No signs of the influence of the diabase dikes on the ore beds have been found. Nor have any traces of dislocations been found in them. Besides this, in the 256 m level of the Central Frunze mine, veins of hydrohematite, penetrating through narrow cracks into the diabase as far as 20 to 30 m from the point of contact have been observed. One also meets with ore bodies distributed along the saddles of dikes of decomposed diabase. The screening role of these dikes is well emphasized by an increase in the dimensions of the ore beds at contacts with the diabase dikes in most places. All these observations show that the martite ores were formed later than the diabase dikes. They are also very important criteria for proof of the supergene origin of the rich ores of the Saksaganian region.

It has been established that the fissured weathered zone is developed primarily within the Saksaganian syncline; the ferruginous quartzite in the structure of the Saksaganian anticline was not accessible for deep circulation of the circulating ground water which, without penetrating to the depths of the folded structure, quickly sank away along the limb of the anticline. Hence, signs of deep weathering are present only in the K. Liebknecht mine along the diagonal fracture. Deep circulation of surface water took place largely along the zones of contact of the rocks of the middle and upper basal beds of the Krivoy Rog series, modified by the

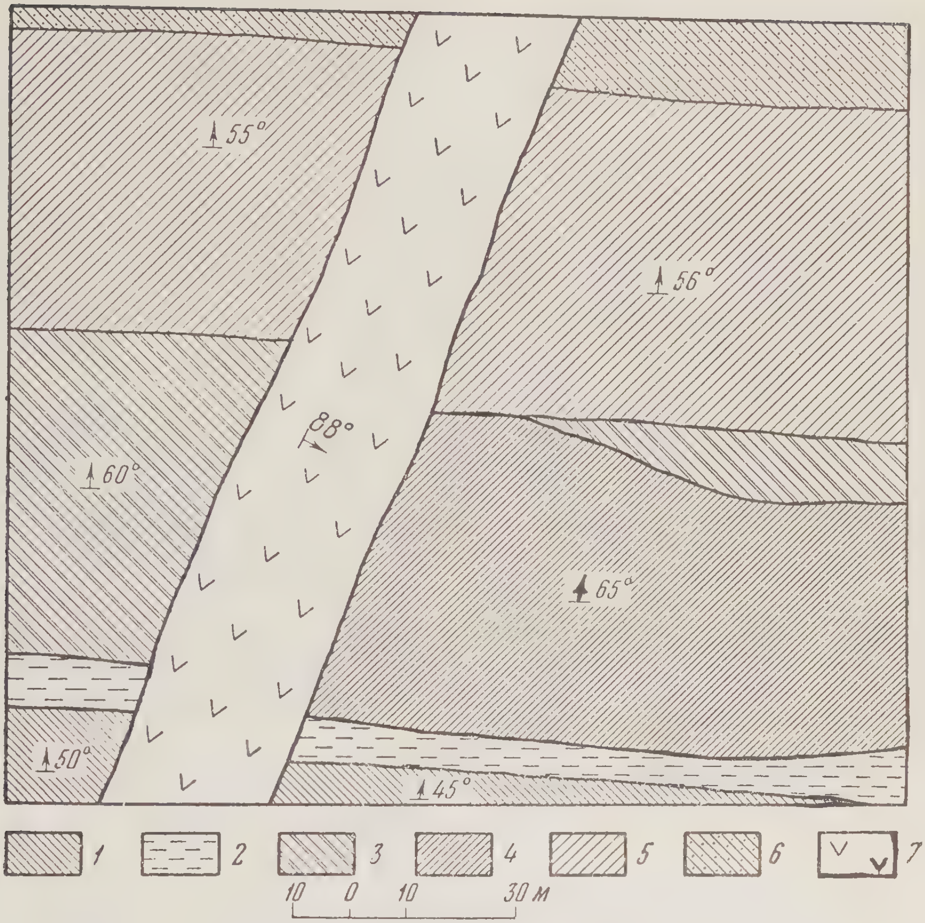


FIGURE 6. The relationship (in plan) of the ore bed with the host rock and diabase dike, which formed prior to the ore formation. XX Parts'yezda mine, Tel'man Shaft, Glavnaya deposit.

1 - Chlorite and hydrohematite schist; 2 - Hydrohematite quartzite; 3 - Jaspilite; 4 - Martite ore; 5 - Schist and hydrohematite quartzite with Martite; 6 - Medium layered martite quartzite; 7 - Olivine diabase dike.

overthrust and underthrust tectonic movement.

The basic favorable factors for the formation of a fissured weathered zone within the Saksaganian syncline are:

(1) The form, structure and bedding of the folded structure itself;

(2) The presence in the rocks of iron-bearing beds or of large fractures near them, accompanied by "feathered" cracking and by zones of crumpling;

(3) The relatively low temperature metamorphism of the primary sediments with the preservation of the paragenetic sequence of chlorite-talc-calcite; in contact metamorphic zones along intrusive bodies, the ancient weathered zone is not formed;

(4) The closed surface water circulation system, which is due to the presence of rocks of differing permeability in the section of the metamorphic belt;

(5) The absence of any endogenic post-magmatic metasomatic processes acting on the weakly metamorphosed rock.

In the Saksaganian region, the processes

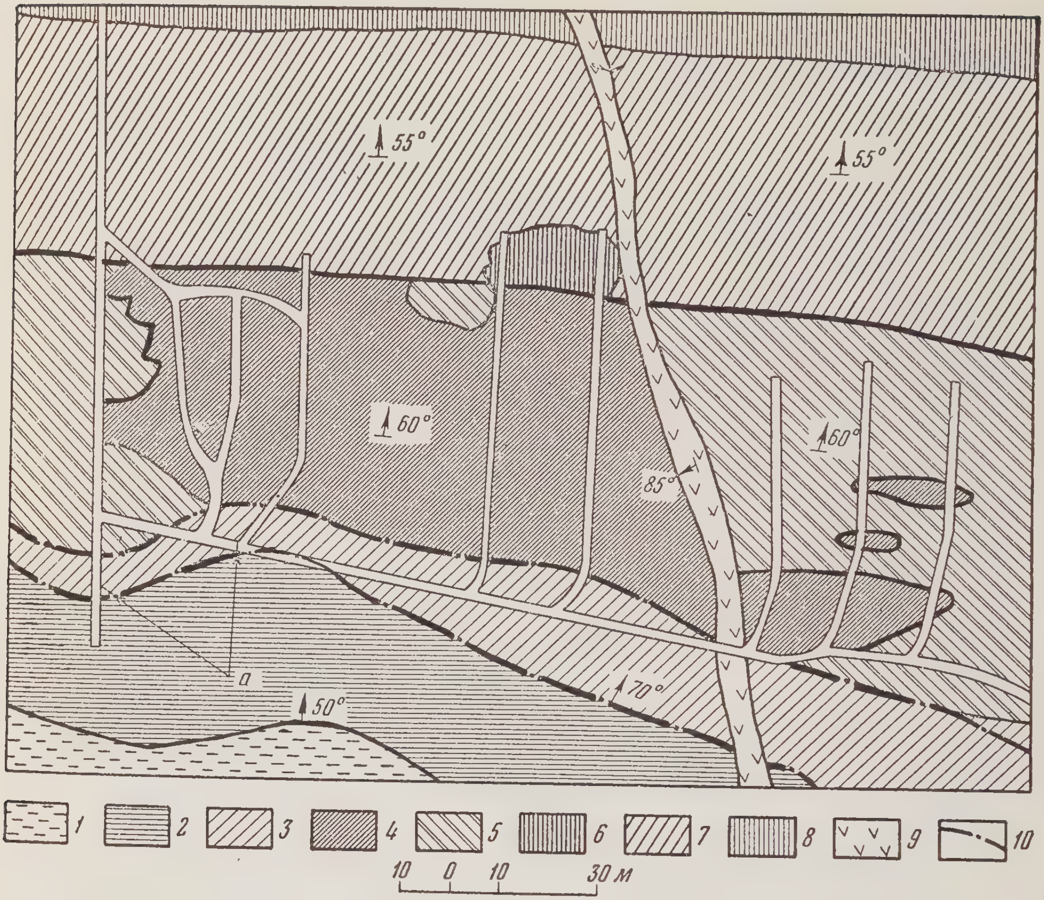


FIGURE 7. The relation of the ore bed to the host rock and the diabase dikes. Frunze mine, Central'naya shaft, 186 m level.

1 - Phyllite; 2 - Talc schist; 3 - Chlorite schist; 4 - Martite ore; 5 - Jaspilite; 6 - Hydrohematite ore; 7 - Schist and hydrohematite quartzite with martite crystals; 8 - Martite hornstone; 9 - Diabase dike; 10 - Zones of tectonic disruption (a) fine brachifolds, related to the formation of the underthrust.

of alkaline and magnesian metasomatism are manifested quite unevenly. Alkaline metasomatism is developed in the regions between the ore nodes or productive areas of the region, mostly in the rocks of the 6th iron-bearing stratum. Morphologically, the zones of its appearance are represented by columnar bodies, the elements of the bedding of which are determined by the stratification of the rocks containing them.

The dimensions of such bodies are: length 300 to 700 m, thickness 100 to 150 m, area 30 to 100 m^2. The dimensions increase with depth.

Rocks which were subjected to alkaline metasomatism are also found within the ore nodes in the Krasnaya Guardiya Lenin mines. They are preserved in the form of islets with sinuous outlines among the oxidized and leached masses, and only in isolated localities are they subjected to the intensive influence of weathering agents. Generally, among these metasomatically altered rocks the fissured weathered zone is not formed. The metasomatites show no spatial connections with the rich ore beds of the Saksaganian type.

Up to the present, the fissured weathering zone of the Saksaganian region has been traced to a depth of more than 1,000 m, and at least to this depth, the character and intensity of oxidation of the ferruginous quartzite is not altered significantly.

It is noteworthy that of 800 to 900 m,, ferruginous silica or "shelestukha" occurs at depths of 800 to 900 m.

Such a great depth of the weathered zone and the absence of clearly formed zones in its structure can be explained by the crust being developed along fractures in the deep deposits.

The large longitudinal, diagonal and transverse dislocations, formed contemporaneously with the folds, opened up paths for migration of surface water, to a depth which in some localities was determined by the depth of the trough of the synclinal structure.

THE CAUSES FOR THE DISTRIBUTION OF IRON-BEARING DEPOSITS OF THE SAKSAGANIAN BELT IN THE FORM OF ORE NODES OR IN LINEAR ZONES

Weathering proceeded quite unevenly both along the length and width of the metamorphic belt, and its distribution is closely associated with the character and properties of underground circulation and distribution channels, and also with the lithologic composition of the rocks and their physical properties.

Along the length of the Saksaganian syncline, in the region between the Dzerzhinskiy mine in the south and the Lenin mine in the north, the area of development of a fissured weathered zone is clearly divisible into six regions, encompassing a series of linear belts of oxidized and leached ferruginous quartzite. All the ore nodes or other types of iron-ore deposits of the region are distributed within the weathered zone. Between the productive areas, the fissured weathered zone is not formed, and therefore ore beds are not present.

The distribution of the ore nodes along the Saksaganian strip is determined by the presence of areas favorable for mineralization along the fractures in the weathered zone. The ore beds are present in the form of linear belts corresponding to the topographic grain of the surrounding terrain. The assertion of Ya. N. Belevtsev [1] on the essential role of transverse anticlinal folds in the locality of mineralization is not supported.

The relation of the rich iron ores to the fissured weathered zone defines the general pattern of their spatial distribution. This pattern is shown by the absence of ore beds among the unoxidized and unleached parts of the ferruginous quartzite in the Saksaganian region.

It is characteristic that in every ore node, mineralization is confined as a rule to two or three, and sometimes four beds. This is represented by groups of closely packed ore beds extending in a broken chain within the host rocks. The multiple distribution of the ore beds is related to systems of parallel fracture zones at different stratigraphic levels in a folded complex (see figs. 2, 3, 4, 5).

A very important characteristic of geologic structures of the Saksaganian type is the development of mineralization along the favorable beds, in the form of a complete system of ore bodies following one after the other and connected together with longitudinal and diagonal disruption.

The presence of this structural connection between the closely-placed ore beds, in one ore-bearing strip, explains the fact that the ore bodies alternately become divided into a series of beds and nests along the length and depth or merge together into one large layer.

The geological structures of the ore fields have been quite inadequately classified. One of the most important tasks for detailed study of the tectonics of the ore nodes of the Saksaganian belt is an explanation of the patterns of structural connection between the separate but proximate ore beds.

THE ROLE OF THE LITHOLOGY AND TEXTURE OF THE IRON-BEARING ROCKS IN THE LOCALIZATION OF IRON ORE DEPOSITS

As has been shown above, the iron ore deposits of the Saksaganian belt represent the products of exogenically weathered, ferruginous quartzite. In some cases, the processes of transformation of ferruginous quartzite into rich ore consisted primarily of the leaching of silica from them resulting in the formation of friable ores; in other cases, the addition of iron hydroxide, brought about the formation of dense ores. Among the friable and dense ores, there are transitional stages present. The dense ores are in some cases formed by the quartzitization or silicification of the friable ores. Silicification manifests itself in the appearance of irregular fine secretions of quartz or chalcedony cutting the laminar texture.

During the processes of leaching and replacement there must have occurred considerable subsidence; this is borne out by the decrease in depth of the ferruginous

beds in areas where the rich ores are developed, by the development among the ore bodies of disharmonic micro-folds arising when the rocks subsided, and also by the presence of regions with a fragmentary structure.

The spatial distribution of the ore beds is almost always limited to areas of distribution of the ferruginous quartzite. Their petrologic texture is not only a direct prospecting clue, but also defines the quantitative characteristics of these deposits. In places, there is a sharply defined dependence of the mineralogical composition of the ores on the rocks containing them. In the jaspilites or pure ferruginous quartzite, mortite ores were formed; in the siliceous ferruginous quartzite -- hydrohematitic martite were formed; and in the ferruginous-siliceous schist -- hydrohematite ores were formed.

processes is completely unfavorable.

A general pattern is observed in the confinement of mineralization to definite beds of ferruginous quartzite. Thus, if the iron-bearing beds developed in the region are listed according to their degree of saturation with ore deposits, the following order results (excluding the Dzerzhinskiy mine) (see Table 1).

Table 1 shows that the layer most saturated with ores is the ferruginous quartzite of the 5th iron bearing layer, occupying only 3.1 percent of the area of the Saksaganian syncline, but accounting for 60 percent of its ore. In this layer irregular sheet-like ore bodies of large dimensions occur which are localized only within the above-mentioned areas of distribution of the weathered zone. In places where processes of weathering along fracture zones are not developed, the 5th layer, together with the other iron-bearing layers, does not contain ore.

TABLE 1.

No. No. P/P	Name of iron-bearing horizon	Development of the various horizons (in percent)		Average number of deposits	Percent of average ore area
		In the stratigraphic column	Of the area of the region		
1	1st (K_2^{1Fe})	1.0	0.6	7	2.0
2	2nd (K_2^{2Fe})	2.0	2.0	11	2.7
3	5th (K_2^{5Fe})	3.7	3.1	45	60.0
4	6th (K_2^{6Fe})	13.5	12.2	70	33.5
5	7th (K_2^{7Fe})	36.4	23.8	7	1.8
	Total	56.4	41.3	140	100.0

It should be noted that all three types of ore commonly form complex beds in which gradual transition from one type to another occurs, thus suggesting their common origin.

Not all the ferruginous quartzite is subjected to weathering to the same degree. Pure ferruginous quartzite (jaspilites), devoid or almost devoid of iron silicates, is the most favorable type for development of oxidation and leaching processes. The weakly metamorphosed siliceous ferruginous quartzite is less suitable and the ferruginous quartzite altered by intense metasomatic

The sheet-like ore bodies, distributed within the area of the 5th iron-bearing layer, represent the most important group of ore beds of the Saksaganian region. Usually they are complicated along their length by columnar swellings and narrowings, and with increasing depth they split and break up into separate beds, branch out, and, in places, reunite, at greater depth, into one ore body. The length of the ore beds ranges from 150 to 1,000 m, the thickness from 10 to 70 m, and the area

from 7 to 30.0 (?) m^2.

The intensity of mineralization of the 5th iron-bearing layer is to a considerable extent due to the presence of fine-grained jaspilite, distinguished by a very finely foliated structure, the folia being 1 to 2 mm in thickness, and also by a high iron content, as much as 42 to 45 percent.

Where weathering affects the rocks of the 1st, 2nd and 6th iron-bearing layers, the mineralization is considerably less defined, and is represented principally by columns and block-shaped beds. The columnar ore bodies in horizontal intersections generally have a roughly lens-shaped, elongated form with a sinuous outline. Commonly, they are oval in form, somewhat elongated in the direction of the host rocks, but in comparison with the block shaped and nodular beds, they are characterized by a smaller degree of change in dimensions and form with increasing depth. The block-shaped beds are distinguished from the columnar by smaller dimensions and a more complicated structure; their area of contact changes sharply from layer to layer.

These iron-bearing beds are composed of medium-grained foliated ferruginous quartzite, the jaspilite is not developed in them to any extent, but seams of ferruginous, siliceous schist are quite common. The iron content in the ferruginous quartzite ranges from 20 to 40 percent. The 7th layer of ferruginous quartzite, composed largely of roughly foliated siliceous ferruginous quartzite, includes a small quantity of small ore bodies.

Formation of the ore beds of the Saksaganian belt are determined by the conditions of deposition of the rocks containing them -- usually they are extended in a northeasterly direction and have a dip generally concordant with that of the containing rocks, approximately 35 to 80°. The ore bodies do not as a rule extend beyond the limits of the rocks which correspond with them in composition. Usually they merge gradually into the rocks laterally and contain relics of the host rock.

It is noteworthy that mineralization here is determined by the beds or layers of favorable or slightly permeable rocks which overlie and underlie the ferruginous quartzite beds.

The schist served as impermeable or screening surfaces for ground water circulation in the fracture zones of the ore-bearing beds. As a result, in each separate tectonic zone, there was created an independent regimen of ground-water circulation that essentially determined the extent of mineralization.

For example, the ground-water circulation in a fracture zone of considerable thickness sharply differs from that of a narrower zone. In a zone of extensive tectonic disturbances, the quantity of circulating groundwater is large, and this is related to the formation of the large ore beds. The slight development of mineralization along small tectonic fractures is due to the smaller surface area exposed to the ground water.

The most important processes of transformation of the host rocks are martitization and hydrohematitization. Both processes are spatially and genetically closely associated with the formation of ore beds. They precede the leaching of the quartz, i.e., the formation of ores was a preliminary stage. All the ore beds within the Saksaganian region are bordered as a rule by a solid coat of martitized and hydrohematitized rocks. In the whole region, the ore beds are the most extensive of the altered rock. The most oxidized and leached ferruginous quartzite is located around the ore bodies; with increasing distance from the ore bodies the intensity of weathering decreases.

The zones of altered rocks provide reliable prospecting criteria; the zones of leached ferruginous quartzite, at present serving as indicators for exploitable deposits, are of special importance. For a detailed mapping of the weathering zone the relations between the altered rocks and mineralization must be classified for the prediction of mineralization at depth and in neighboring areas.

THE RELATION OF ORE BEDS TO FRACTURE AND FAULT ZONES

The mineralogic composition and the physical properties of the rocks do not fully determine the localization of ore bodies. The tectonic preparation of the rocks is also of the utmost importance. Ore beds are formed only on the chance combination of favorable lithologic properties and structural and geologic circumstances.

Until recently, the basic structural factor in the formation of rich ore beds has been ascribed to the micro-tectonic elements and especially to the small folded structures arising among the ore beds as a result of their subsidence, as well as the fine fissuring. Lately, this role is being ascribed to transverse anticlinal folds.

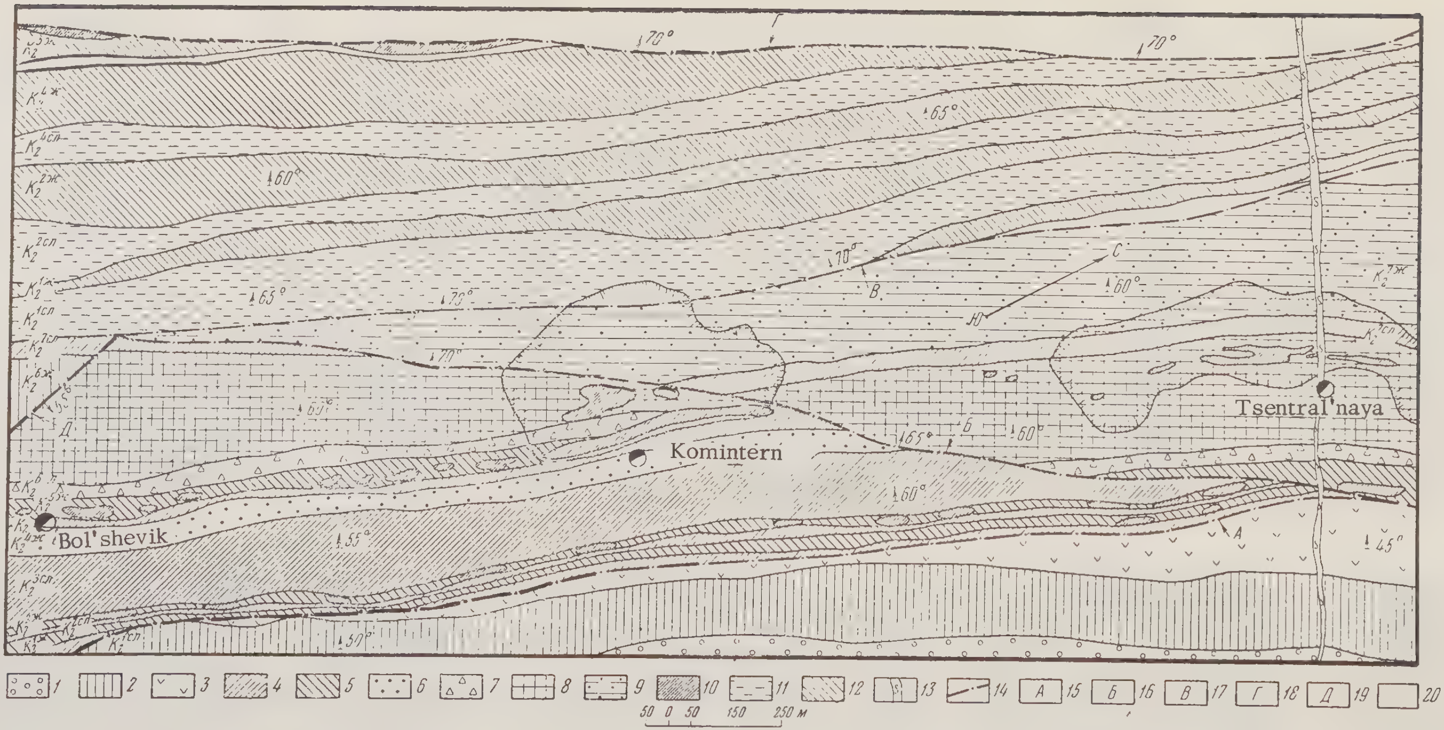


FIGURE 8. Geologic map of the region between the Bolshevik, Komintern and Tsentral'naya shafts.

1 - Arkose; 2 - Phyllite; 3 - Talc schist; 4 - Quartz-sericite, chlorite and hydrohematite schist; 5 - Martite hornstone and jaspilite; 6 - Schist with subordinate seams of ferruginous quartzite; 7 - Schist and hydrohematite quartzite with martite crystals; 8 - Martite quartzites; 9 - Hydrohematite martite quartzite; 10 - Martite ore; 11 - Schist; 12 - Amphibole - chlorite - magnetite and carbonate-magnetite, hematite-martite, and hydrohematite-martite quartzite; 13 - Diabase dikes; 14 - Zones of tectonic disturbance; 15 - The Eastern underthrust; 16 - Diagonal reverse thrust fault; 17 - Saksaganian overthrust; 18 - Western overthrust; 19 - Diagonal trough fault; 20 - Schists of the upper section of the Krivoy Rog series.

Thus, the diagonal reverse fault represents a structure along which movement took place contemporaneously with folding. The enormous stresses to which the rocks were subjected during the movement of the faulted blocks of the folded structure brecciated the adjacent rocks, creating a path for the deep penetration of weathering agents and leaching in the ferruginous quartzite.

Because of the irregularity of the movement and also because the zone of diagonal fracture cuts across various rocks reacting differently to the tectonic stresses, its width is variable and ranges between a few tens of centimeters to 8 m.

The study of this reverse fault in the mine workings of the "Komintern" shaft of the Oktyabr'skaya Revolutsiya mine and the Tsentral'naya shaft of the Frunze mine has shown that the fracture zone commonly occurs in the form of a group of closely-spaced surfaces, in places merging into each other or branching out. But due to the fact that, during the development of the fault along a group of surfaces, the movement was greatest along the main surface, in most cases is sharply developed.

A characteristic property of the diagonal fault is the presence of a fine network of feathery fractures in both its walls. These accompany the fault zone both in the iron-bearing and shistose beds. In places, the fault is accompanied by drag-folding and by small brachifolds..

The iron-ore beds of the Oktyabr'skaya Revolutsiya mine, related to the tectonic structures formed by the movement along the diagonal reverse fault and the eastern underthrust, occupy a central position in this ore node (see fig. 2).

This geologic plan of the 367 m level is a convincing illustration of the relation of the ore beds to the fault surfaces. Along the main diagonal fault, the ferruginous quartzite of the 5th iron-bearing layer is mineralized completely and forms a very large blanket-shaped bed. The intensity of mineralization of these rocks gradually weakens in proportion to the distance from the zone of disturbance. The ore beds developed in the rocks of the 6th and 7th iron-bearing layers are confined to the zone of longitudinal faulting, connected with the main diagonal fault. The region of increased thickness or columnar swelling of the ore bed in the region of the main cross-cut of the Komintern shaft is confined to the region of contact of the main fault with the fine network of cracks. The distribution of the ore beds within the 1st and 2nd iron-bearing layers is determined by the longitudinal underthrust fault running through the hanging wall of the 2nd iron-bearing layer.

It must be emphasized that here within the ore field of the Oktyabr'skaya Revolutsiya mine our detailed geologic mapping has not established the so-called transverse anticlinal folds to which Ya. N. Belevtsev [1] relates the ore formation. The bends in the ore-bearing layer are connected with the formation of the diagonal reverse fault and the eastern underthrust -- i.e., they represent the reversal of the beds at the fault surface.

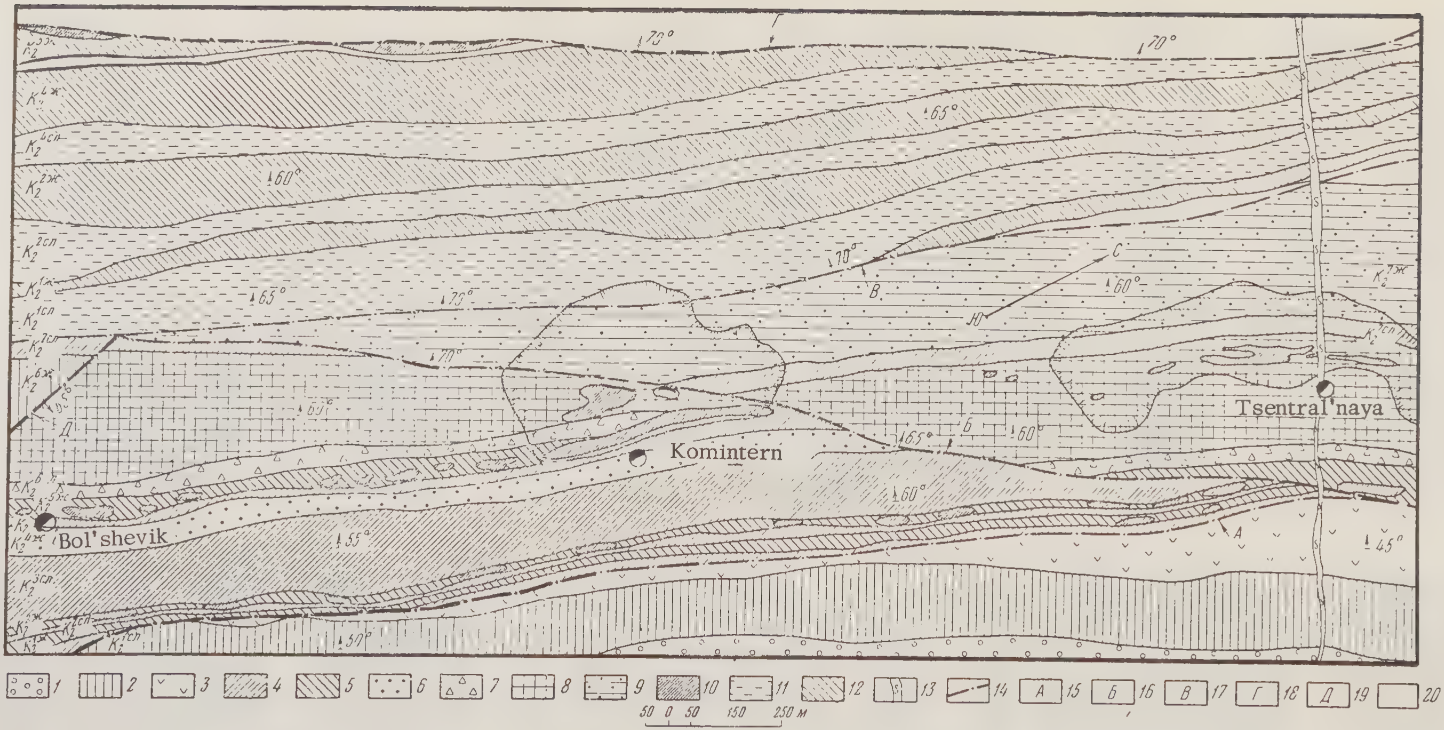
In the region of the Frunze mine, the ore bodies are distributed in four small chains confined to the 1st, 2nd, 5th and 6th iron-bearing layers. The ore field is a clear example of the significance of the faulting in the localization of rich ore beds (see fig. 3). In distinction from the Oktyabr'skaya Revolutsiya mine, the longitudinal faults play the major part. The ore beds confined to the 1st, 2nd and 5th layers are connected with the eastern underthrust, which appears in the form of several parallel plates, the ore bodies of the hanging wall of the 6th ore-bearing layer are connected with the longitudinal overthrust faults. In the central part of the mine, at the contact of the diagonal reverse fault with the eastern underthrust, transverse fractures contain diabase dikes. These have an almost vertical (75 to 85^{o}) dip to the south, and, in places, dip at the same angle to the north. Their thickness and extent increases with increasing depth.

Thus, the spatial distribution of the ore beds is determined also in this mine by the zones of fractures; dipping transverse anticlinal folds were not found. The bend in the rocks in the central part of the mine, with the convexity to the west, is determined by faulting.

In the region of the Frunze mine, as a result of the gradual closure of the Saksaganian anticline, the Saksaganian overthrust gradually dies out by splitting into a number of progressively smaller and smaller fractures. Finally, in the region of the Gleyev ravinė, the overthrust fades out completely.

This primary ore complex of the Bolshevik mine was formed at the contact of the diagonal thrust fault, connected with regional faults -- the Saksaganian overthrust and the eastern underthrust -- and the interbed displacement running along the contact of the 5th schistose and 5th iron-bearing layer. The contact of the diagonal thrust fault with the Saksaganian overthrust is shown in fig. 8.

Within the region dividing the productive



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Within the region dividing the productive

areas of the Frunze and XX Parts'yezda mines, the zone of oxidation has spread to a depth of 150 to 300 m in the rocks of the 5th and 6th iron-bearing layers. Here the ancient weathered zone did not develop, evidently because of the absence of extensive faulting.

The ore nodes of the XX Parts'yezda and Krasnaya Gvardiya mines are separated from each other by an oreless zone about 600 m in length, bordered in the south by a large transverse reverse fault, and in the east and west by longitudinal fractures of the overthrust and underthrust types.

Here, the major role in the distribution of the ore-bearing beds is taken by the eastern underthrust and the smaller fractures connected with it. It is developed in the form of several parallel plates among which one extends along the flat side of the 5th iron-bearing layer. The ore beds connected with the formation of plate-like underthrusts and with the contacts of the finer diagonal faults are distributed in the 5th and 6th iron-bearing layers. They extend as small parallel chains along the zone of underthrusting.

It has been established that the largest and most productive ore beds are formed in the area of contact of the longitudinal and diagonal faults. As can be seen from fig. 7 the ore bodies of the central shaft of the XX Parts'yezda mine are developed in the fault zones; the opinion of Belevtsev [1] on the presence of a large fold and of transverse anticlinal folds is not supported by structural mapping.

The productive areas of the Krasnaya Gvardiya mine are separated from the ore node of the Lenin mine by an oreless zone of about 2 km.

In this area, distinguished by comparatively intensive alkaline metasomatism, a fissured weathered zone is not present. The layers of ferruginous quartzite and other schistose strata separating them were subjected to processes of contemporary weathering, the depth of which ranges from 10 to 200 m.

The main shoot of the Lenin ore body embraces a strip of iron-ore formations 3.5 m in width, 1.3 km in length. The productive areas of the ore-bearing layers have a length of 1.3 km and occupy the central part of the ore field.

The ore beds are developed within the 2nd, 5th, 6th and 7th iron-bearing layers in the form of extended zones (belts) and in combination form an ore lode bordered by zones of fracture in the south, north, east and west.

It should be noted that in the opinion of Belevtsev, the fundamental structure of the ore body of the Lenin mine, determining the intensity of mineralization and distribution of ore beds, is an anticlinal flexure. He writes, "The formation of such a flexure, just as of more sloping transverse folds was accompanied by foliation of the rocks, and as a consequence the jaspilites in these areas became intensively mineralized and beds of rich ore were formed. In the bend itself, one observes almost solid mineralization" (p. 1 [31]).

The folding, a consequence of the development of diagonal fractures (see Geological plan of the 447 m level, fig. 5), are regarded by Belevtsev as anticlinal or flexural folds. As proof of the connection between the ore beds and these supposedly existing anticlinal folds, he asserts that in the confines of the flexural bend, one observes an almost solid mineralization of ferruginous quartzite. Actually, the jaspilites of the 5th iron-bearing layer are the most favorable rocks for mineralization in the region of folding of the beds discussed, developed between the main diagonal faults (see fig. 5 marked with a D) and the southern diagonal fault, penetrating south of the trunk of the Ordzhonikidze shaft. These contain only one comparatively small bed, and indeed this gets decidedly smaller with depth, and at 350 m below the surface completely fades out (see fig. 1).

It has also been established that the ferruginous quartzite of the 5th iron-bearing layer, near the fault surface of the southern diagonal fault, were deformed during folding, but even so they do not contain beds of rich ore. This is explained by their exposure to weathering processes only near the surface, which is evidently related to their subjection to intense alkaline metasomatism, making them more resistant to weathering and leaching.

Thus, the distribution of rich ore beds depends on the distribution of tectonic structures favorable for mineralization, created as a result of the development of longitudinal diagonal and transverse faults. Of especial importance in the formation of rich ore beds here are the longitudinal faults of the overthrust and underthrust type.

The Osnovnaya Kar'yera-1, Vostochnaya, Severnaya and Klubnaya deposits are confined to the zone of the main diagonal fault. The ore bodies found to the west of these beds are connected with the longitudinal faults. The beds of the 1st and 2nd iron-

bearing layers are developed near the zone of the Vostochniy underthrust, but the Yuzhnaya Ventilyatsionaya ore bed is connected with the southern diagonal fault.

As mentioned previously, the martite ore beds -- the Klubnaya, Yuzhnaya Ventilyatsionnaya and 1st Saksaganian bed -- merge at depth into unoxidized magnetite ferruginous quartzite, with the appearance of having been subjected to alkaline metasomatism.

In concluding this short examination of the iron ore deposits in the Saksaganian syncline, we feel it necessary to remark that martite ore beds of the Saksaganian type found in the region of the Chevonno-Gleyev group are also connected with the fissured weathered crust.

The ore deposits of the Chevonno-Gleyev group are developed along the contact between the middle and upper sub-series of the Krivoy Rog series, which is complicated by the so-called Zapadnyy underthrust. The zone of fracture has a sinuous outline both in length and in depth. The overthrust cuts the separate beds, and in places determines the tectonic cross-layering of the rocks of the middle and upper sub-series.

Mineralization here is represented by several types of rich ore beds of different origins. The redeposited sedimentary ores of the weathered zone are most common here. These were formed at the time of the splitting of the middle and upper sub-series of the Krivoy Rog series and were metamorphosed along with the rest of the Krivoy Rog series in the main stage of folding and metamorphism. They are represented by sheet-like ore bodies lying on the rocks of various levels of the middle sub-series, and complicated by chlorite-amphibole-magnetite and chlorite-carbonate-magnetite ores.

Less widely distributed are the iron-mica-magnetite ores representing metamorphic remnants of the weathered surface zone. These ores, formed at the time of the split between the middle and upper sub-series of the Krivoy Rog series, are localized at the top of the iron-bearing beds of the middle sub-series.

Even less developed in this region are the martite ores formed in the post-Proterozoic fissured weathered zone. The formation of these ores is determined by the development of the overthrust mentioned. The ore bodies are usually confined to the ferruginous quartzite layer which is in contact with the surface of the overthrust. Outside the zone of this overthrust, the development of martitic mineralization of the Saksaganian type does not occur in the ferruginous quartzite.

CONCLUSION

1. It is firmly established that the martite and hydrohematite ores of the Saksaganian belt were formed in a linear, faulted, fissured, weathered zone, after folding and after the cessation of all endogenic and magmatic processes in the Krivoi Rog region.

2. The relation between the ore beds and the described fault and fracture zones permits an understanding of the factors affecting the distribution of the iron-ore deposits, and disproves the widely held opinion that the fundamental structural factor in the process of mineralization can be ascribed to the so-called anticlinal folds in the rocks.

3. The spatial distribution of weathering and ore-formation is largely determined by the fault tectonics in the host rocks, and also by the physical and chemical properties of these rocks. Thus, a detailed study of fault tectonic is vital for a more rational approach to the problem.

4. All the iron-ore deposits of the Saksaganian region are strictly limited by the extent of the weathered zone. Ore beds are not formed among the unoxidized and unleached areas of the ferruginous quartzite. The relation of the rich iron ores to the fissured, weathered crust determines their spatial distribution. Hence a knowledge of the morphology of the weathered zone and the pattern of formation of ore beds in it must be used as a basis for investigation and exploratory work on the iron ore deposits of the Saksaganian belt.

At the present time, in the Krivoy Rog basin, considerable amounts are being wasted on costly investigation work, questions, the answers to which could be obtained merely by a study of the weathered zone.

These geologic factors favorable for the development of weathering processes and ore formation, and also the pattern of distribution of the iron ore deposits which we have described will help towards developing a correct view in investigation and exploratory work, and should increase their effectiveness.

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NEW DATA ON THE GEOLOGY OF THE PRECAMBRIAN OF THE ALDAN

by

N. G. Sudovikov

ABSTRACT

The main problems of Precambrian geology are examined in the light of data obtained from new investigations by the Laboratory of Precambrian Geology AN. SSSR. Some statements of A.A. Kadenskiy are critically analyzed as well as the scheme of succession of geological events which he proposes for the Aldan Precambrian.

* * * * *

From 1952 to the present a group of geologists of the Laboratory of Precambrian Geology, Academy of Sciences, U.S.S.R., have investigated the mining regions of the Aldan Precambrian shield. In this group are G.M. Drugova, M.D. Krylova, L.V. Klimov, D.A. Mikhaylov and the author. In 1955, the first stage of these investigations was concluded; the results are currently being collected in the form of a monograph. Some of the results obtained before 1953 have been published in articles by N.G. Sudovikov and M.D. Krylova [4, 5 in which some new data were presented on separate problems dealing with the geology of the Aldan Precambrian. The data and conclusions in these articles are fully substantiated by investigations performed after 1953, covering almost all of the Aldan mining area. The results of the later work, while not essentially altering the conclusions drawn in the previous articles, considerably widen their scope, and give a number of supplementary deductions on the geology of the Aldan Precambrian.

At present, the necessity for publication of the new data is important, primarily with the aim of communicating the information obtained, but partly because of critical statements by A.A. Kadenskiy, giving an untrue interpretation of our factual data [1].

The elaboration of new proposals and of the established sequence of geologic events in the Aldan Precambrian began with the discovery of numerous metasomatic diopsidic and diopsidic-amphibolitic veins in large areas of the basin of the middle segment of the Aldan, and near the Chuga and Amedicha rivers. About 50 localities where they occur have been found in an area of 100 by 150 km. Detailed petrographic and chemical study of these veins leaves no doubt as to their metasomatic origin. Field investigations have substantiated these findings. It has been established by field observations that the formation of the veins took place along cracks. In some cases, traces of such cracks are preserved in the form of narrow veins where replacement of the enclosing rocks developed symmetrically with them ([4], fig. 4, 6). Compression of the network of veins where replacement took place leads to a condition where the enclosing rock occurs, in places, within the dense vein in the form of relicts, preserving the original texture and orientation ([4], fig. 1, 3, 5).

The new data make it clear that processes moved in a definite direction (one of the results being formation of iron-magnesium-calcium-silicates), but also that changes occurred in the composition of the admixed material with time, thus making it possible to examine the zonality of the veins and the genesis of axial phlogopitic zones and of feldspathic axes in some metasomatic veins.

Study of numerous petrographic analyses, supports the earlier conclusion that the introduction of large quantities of iron, magnesium and calcium during the process of metasomatism was the chief factor determining the type of metasomatism [4]. Any method for treating data from the chemical analyses easily determines the type of metasomatism in the vein formation of the

Aldan. However, the method of T. Bart is especially suitable because it provides for quantitative evaluation of the material introduced under conditions where the volume is preserved, and also makes it possible to compare data on the appearance of metasomatism under various conditions [6 and 8]. All observations on the form of veins not exposed to later deformation give evidence of their formation in a solid medium. In the majority of cases the veins have linear and, as a rule, intersecting contacts. The formation of veins in a solid medium is fully supported by the absence (in all veins not deformed later) of any traces of structural disturbance which formed during the metasomatism and of any minerals entering the wall-rock.

Intersecting metasomatic bodies occur in crystalline schist and gneiss of differing composition, in amphibolite, quartzite, and carbonate rocks of the Iengrsk series, and in various granitoid rocks. It is characteristic that the metasomatic veins in many places cut migmatites of differing composition, but the composition of the veins is essentially uniform.

Of especial interest is the fact that these detailed investigations brought to light evidence of later deformations within a wide territory up to 15 km in diameter. These veins had been affected by some stage of iron-magnesium-calcium metasomatism. Study of numerous examples of structures gives indisputable proof of the plastic deformation of the veins and of the ability of the granitoid material of the rocks in the walls to flow. In some regions, the angular blocks, containing parts of veins with a zonal construction, are turned round and distributed in disorder in the granitoid rock having a flow structure. These structures are convincing evidence that the deformation took place in conditions of partial or complete fusion of the gneiss and its transformation into new granite, preserving the angular blocks and internal structures of the veins of more basic omposition. The comparison of such deformations with the data mentioned previously on the intersecting and undeformed veins indicates a rise in temperature, to the melting point, only in areas of deformed veins and after complete formation of the metasomatic veins. This rise in temperature probably reached 750° C. and the formation of the metasomatic veins, judging by the observed juxtaposition of rocks of different composition, and taking into account the composition of the same veins, corresponding to the amphibolite facies, must probably have been at 500 to 600° C.

The main results of study of the iron-magnesium-calcium metasomatism, carried out in the complex, with investigations of other geologic manifestations described in the present article, can be briefly summarized by the following conclusions, that follow directly from the above resume of the composition, structure, and origin of the veins, and their structural relation with the host rocks.

1. As a result of these investigations, a geologic basis is established for the separation of two granites differing in age, separated in time by a period of iron-magnesium-calcium metasomatism. The distinction between them is characterized, in distinction from periods of granite formation, by the solid state of the mass of crystalline schist and gneiss and metamorphic rocks in the middle stages of an amphibolitic facies. Previous investigators took as a basis for such a division, largely typological signs and data on comparison with other regions, that are in no way comparable in reliability with the new criteria given above for separation of the granites.

2. The new data permits description of the ultrametamorphism and recognition that the second period metamorphism locally intersected erosional surfaces. This is easily explained by the proximity of the boundary of the metamorphic and ultrametamorphic transformations to the contemporary level of erosion during this period and, quite naturally, by some unevenness in the granite surface. Locally, ultrametamorphism was expressed only in the local fusion and in the formation of relatively small granite masses which had undergone small intrusive movements. Such a characterization of this period, of course, could not have been given in the works of previous investigators because this same period had not been recognized by them as a time of repeated appearances of ultrametamorphism.

3. The new investigations also permit the characterization of the granites second in age as having been formed largely as a result of repeated fusion of the earlier migmatized and granitized rocks of the Iengrsk series and assimilation of silicic rocks. This conclusion is in full agreement with the fact that the granites of the second period have an aliascitic character and consequently their genesis can be regarded as connected with the processes of repeated selective fusion. The alaskitic character of the granite was determined by its genesis, in the given conditions, from felspathized quartzite and leucocratic gneiss that had been subjected to repeated fusion. Such an explanation could not have been geologically and petrologically substantiated in previous investigations.

4. As a result of these investigations, the new interpretation of the sequence of geologic events has been shown to be well founded. It reveals several very important stages in the development of the Precambrian formations. After sedimentation, and probably volcanic activity, folding and regional metamorphism occurred. It has been demonstrated in the literature that regional ultrametamorphism developed after regional metamorphism and that it can be viewed as a higher stage characterized by fusion of the substratum and the development of migmatization and granitization processes. Our investigations have proved that after the ultrametamorphism and iron-magnesium-calcium metasomatism occurred. The second formation of genetically different granites occurred directly after this metasomatism, in the territory of the Aldan mining region. Besides clearly intrusive granitoid bodies, whose relation to the second period of granite formation is well established by their intersections with early metasomatic veins, there are related granites which formed from the fusion and granitization of gneiss and other rocks of the Iengrsk series and which underwent relatively small intrusive transpositions, e.g., granitoids at the mouth of the river Chuga.

This sequence of events for the Archean has been established by direct observations of the structural relationships of formations of various ages, and in this it differs from the interpretations constructed by previous investigators, who based their interpretations mostly on the petrographic properties of the rocks, without reliably basing their age on structural data. This new scheme gives a solid basis for judging the age of granites, for which, up to the present, a largely conditional division between the older plagioclase and younger microcline granites has existed.

An important consequence of the establishment of the new interpretation of the sequence of geologic events is the necessity for an examination of interpretation of the genesis of the Aldan iron ores. At the present, after establishment of a complicated sequence of events that played a part in the transformation of the Precambrian rocks, it is not possible to view the formation of iron ore concentrations as a one-act process of sedimentation or metasomatic ore deposition. The recognition of the importance of sedimentation or metasomatism does not reduce the necessity, in the network of new investigations, for a profound study of the importance of other phenomena in the process of formation of the ore deposits.

The new investigations show that in Precambrian time, besides sedimentation and iron-magnesium-calcium metasomatism, an essential part in the formation of the structures of iron-ore masses was played by processes related to the first period of ultrametamorphism, including the regional development of granitization and intensive tectonic activity, that affected selectively fused, heterogenously migmatized rocks. A study of the manifestations of granitization of this period and a determination of their relative importance in the formation of iron-ore concentrations is inevitable at the present time, although for the large iron deposits the role of this factor can hardly be significant, if one takes into account the differential character of the manifestations of granitization (see below).

More important is a study of the tectonic movements of the period of the first ultrametamorphism. The differential character of these movements and their effect on selectively fused rocks suggest the possibility of classification by the process of movements of rock masses differing in composition and in physical state. In the deposits of the Taega group, it is seen that one of the most important properties of the structure of this ore-bearing zone, that has a direct bearing on the determination of the possible presence of ores, namely the discontinuity of the ore deposits, can be explained by the isolation of the masses during differential tectonic movements of the first period of ultrametamorphism.

It is not necessary to insist on the significance in ore-formation of processes of iron-magnesium-calcium metasomatism, the importance of which is beyond dispute after the detailed investigations of L.I. Shabynin and our observations.

Regarding the questions of ore formation, it should be noted that as a result of our investigations it is essential when examining these deposits to take into account the manifestations of ultrametamorphism appearing after the iron-magnesium-calcium metasomatism. Although these manifestations have a local character, as mentioned previously they help in a detailed study because the possibility is not excluded that such regions with deep transformation of the rocks and occasional complete alteration of the structure will still be found within the ore-bearing zones.

From what has been said one can conclude that, in the light of the sequence of geologic events established by us, several corrections and additions can be made to the existing proposals on the genesis of phlogopitic deposits, also.

With regard to tectonic activities, it can be stated that the information obtained from investigations by the Laboratory of Precambrian geology makes necessary a new approach to the analysis of Precambrian structures of the Aldan. At least three important periods in the transformation of the structures have been established from these investigations. After the first period of folding, as has been proved, considerable tectonic activity took place during regional synkinematic ultrametamorphism. After these two periods of deformation fractures developed in completely solidified rock and, after iron-magnesium-calcium metasomatism, local new plastic deformations occurred in rocks subjected to repeated softening on fusion. As has now been proved by special thematic investigations by M.N. Krylova in an area near the mouths of the Amedicha and Chuga rivers, this repeated deformation lead to radical transformation and in places to complete disappearance of elements of the old structures and the appearance of new ones.

Because all the conclusions given above on the geology of the Precambrian Aldan mining area are based strictly on factual material from field and laboratory investigations, they can serve as a suitable answer to the statements of A.A. Kadenskiy. He could use these data for a clarification of all the questions now obscure to him. However, it is absolutely necessary to make some supplementary observations because, for geologists not acquainted with the specific attributes of Precambrian geology in general and of Aldan Precambrian in particular some of the statements of A.A. Kadenskiy may appear to be worth attention.

Firstly, it should be noted that the investigations of A.A. Kadenskiy did not cover the area of the Aldan shield studied by us, and hence his theoretical observations on this area are not based on personal observations.

In the interpretation of the sequence of events proposed by A.A. Kadenskiy for the Aldan Precambrian, the geologic significance of iron-magnesium-calcium metasomatism which he attempts to reduce to the level of a local effect, is not given enough weight.

Completely ignoring the factual data described and illustrated in our article [4], A.A. Kadenskiy views the process of formation of metasomatic veins as "an intrusion into the broken blocks of silicic rocks by 'veins' of diopsidic amphibolite rocks." Apparently this took place at temperatures around 500° in a natural series of processes below the line of metamorphism ([1], p. 67). In his opinion "metasomatism took place under conditions of declining temperature, and were linked up with the influence of granite intrusions of alaskites and biotite-amphibolitic granites." The formation of veins, according to A.A. Kadenskiy, took place with little transposition of material, the source of which "was available in the containing rocks." The formation of veins was accompanied by differential movements "leading to the appearance of extrusive bodies and veins, especially in the zones of cut-off" ([1], p. 71).

All these "ideas" of A.A. Kadenskiy lead to the mechanical incursion, in some way, of material extruded from an amphibolitic facies of the host rocks, with differential movements and regressive metamorphism. No proof of this is given. It is impossible to find in Kadenskiy's article any answer to these questions: Which processes are the cause of extraction of substances from the containing rocks? How can mechanical incursion and extraction in certain zones be combined with extractions from the host rocks of material specifically bearing iron, magnesium and calcium? How can extraction in "cut-off zones" be proved if in veins which have undergone a second deformation there is no trace of disturbance? What proofs are there of clearly regressive metamorphism?

For the substantiation of his vague statements on the formation of veins, A.A. Kadenskiy refers to the work of Edelman [7] in which it is possible to find data purporting to show the higher plasticity of basement rocks in conditions of tectonic deformation. This, in the opinion of A.A. Kadenskiy, explains the "incursions" mentioned of diopsidic-amphibolite rocks into the silicic ones, if differential movements and "boudinage" are brought in ([1], p. 67). Such a conclusion by A.A. Kadenskiy could only be made by an underestimation of the fact that the main vein vein bears no traces of deformation; if traces of deformation in the veins were ever observed ([4], figs. 8, 9, 10, 11) they took place under conditions of plastic deformation of the host rocks, usually granitoid rocks, which had undergone partial fusion.

The possibility that the more silicic rocks were in a more solid state during deformation under conditions of low temperature metamorphism has been known for a long time. A.A. Kadenskiy could bring forward illustrations of this, as, for example, in our work [3]. But these examples have no connection with the interpretation of Aldanian structures, because the geologic conditions of these deformations were quite different, and they only bear out that the basic factor determining the more plastic behavior of the silicic rocks is their containing melt,

the quantity of which increases with the progress of ultrametamorphism. The connection of these deformations with ultrametamorphism is supported by the formation of "inter-boudinage" pegmatites during development of "boudinage" structure of the metasomatic veins, the flowing into the inter-boudinage expanses of a whole mass of mobilized granitoid material with higher degrees of ultrametamorphism and granitization of marginal parts of isolated blocks of the deformed veins.

It is impossible to understand the point of A.A. Kadenskiy's reference to the work of Edelman if one considers that Edelman clearly shows and neatly formulates the conclusion that the plasticity of the granitized rocks is great and increases with the degree of granitization ([7], p. 26). But this conclusion is not new and is known to all those working in the regions of extensive development of ultrametamorphic processes. In this connection, it is useful to draw attention to the fact that the questions of differential movements and relative plasticity of rocks undergoing deformation in regions of granitization have been discussed in the literature for some time [2, 9].

In this separate concrete example one sees A.A. Kadenskiy's apparent disregard not only of the facts set out in our article on the iron-magnesium-calcium metasomatism, but also of the factual material and investigational experience acquired in regions studied in much greater detail than the Aldan shield. The Baltic shield is, for example, such a region.

In connection with what has been said, attention must be turned to the contradiction in the interpretation by A.A. Kadenskiy of the genesis of rocks of the granulitic facies. On the one hand, the wide distribution in this facies of manifestations of granitization are rightly recognized and the extraction of femic elements in these conditions emphasized; on the other hand, an apparent degranitization of these rocks is proposed ([1], p. 70). This contradiction can be viewed only as a result of an obvious misunderstanding by A.A. Kadenskiy of several important attributes of the process of regional granitization, and principally of its differential character. It has been confirmed by many investigators in many regions that not all rocks equally abundant in an area are subjected to granitization to an equal extent. To geologists having any significant experience in investigation of wide manifestations of ultrametamorphism, it is well known that basic and carbonate rocks and also quartzite are highly resistant to granitization. This fact is well supported in the Aldan. Hence it is clear that even in conditions of strong granitization, preservation of these rocks is relatively possible, and the presence of these rocks by itself does not prove a lower degree of regional granitization. It is also clear that the charnokitic series, characterized in general by a more basic composition, preserved this individuality even in conditions of regional granitization. This example explains the presence of large masses of quartzite in the Iengrsk series.

The varying reaction of rocks, differing in composition, to granitization is governed by the variations in content of femic components which are liberated in this process. If, in the regionally metamorphosed rocks, a large quantity of femic rocks are present, they may be preserved in some places among the granitized formations as beds or masses, inside which almost unchanged rocks can remain undamaged. In this way, ore formations such as for example the Aldan iron ore masses, which must be regarded as possessing a very great degree of resistance to granitization, can also be preserved.

Turning to a brief examination of A.A. Kadenskiy's scheme, we would like to mention at the beginning that in it ([1], p. 72) the questions of development in time of processes of folding, metamorphism, deformation at great depth, and ultrametamorphism are not clear. Here can be found unproven and strikingly careless "maps of the sequence of eruptive activity" ([1], p. 72).

According to A.A. Kadenskiy "a transformation in the granulitic facies" took place at the same time as the main folding, and, contemporaneously, there developed manifestations of palingenesis, as well as a general rising of the whole zone. The incursion of alaskitic granites was also contemporaneous, but this incursion was accompanied by granitization and metamorphism in conditions of amphibolitic and epidotic-amphibolitic facies and by the formation of diopsidic-amphibolitic veins and phlogopitic rocks. Such a mixture of manifestations is quite beyond the bounds of geologic imagination. One can only grasp that according to A.A. Kadenskiy, all at the same time, and apparently in one and the same type of metamorphism, the various facies developed -- from the epidotic-amphibolitic to the granulated, inclusively -- both regressive and progressive, along with incursion of granite and formation of phlogopitic rocks, and all this is accompanied by ultrametamorphism and granitization. Such a "scheme" of course is not worth consideration. It can, however, be noted that for the understanding of such a scheme A.A. Kadenskiy is forced to resort to a quite unproved distribution of the various granites in various stratigraphic series, to admit "a capricious distribution of the facies of

metamorphism" ([1], p. 72) and to other unfounded conclusions.

The interpretation put forward by A.A. Kadenskiy gives no answers to a number of important, it may be said, cardinal questions on the geology of the Aldan Precambrian. Guided not so much by the hope of obtaining the answers as by a wish to stimulate further discoveries by A.A. Kadenskiy, one can pose a few of these questions. What proof can be brought for the relationship in place and time of metasomatic diopsidic-amphibolic veins to the alaskitic granites, and where can one observe the physical and also the genetic connections between alaskites and metasomatic veins? What petrologic bases can be brought forward to explain such a connection -- which from our facts does not exist? What made A.A. Kadenskiy ignore the separation in time of processes of fold formation, metamorphism and ultrametamorphism, although it is known that regional metamorphism everywhere precedes ultrametamorphism? If one takes the temperature of formation of metasomatic veins as around 500° C., then how is it possible, accepting a regressive direction for the process, to explain the crystallization of dry magmatic pegmatites after the metasomatic veins, and how, in this connection can one attribute the genesis of pegmatites and metasomatic veins to material of one alaskitic intrusion?

In conclusion, one must emphasize the special necessity for resolving the important questions of the geology of the Precambrian formations by a profound evaluation of the whole complex of tectonism, metamorphism, magmatism, ultrametamorphism and ore formation. Without this, it is impossible to analyze correctly the historical sequence of events and elucidate the most important processes, worth special study. Factual material from direct observations must be made the basis of such comprehensive investigation and play the main part. The final result must be the integration of all the processes in their gradual development in time and space. No correct solution to the question of genesis of structures is possible without taking into account the processing of metamorphism and ultrametamorphism. Without a study of these processes the question of the genesis of granite and many other questions of magmatic activity cannot be solved. One cannot solve major questions of geology in isolation. A disregard of the main demands of method in the study of complex manifestations will not lead to positive results. If A.A. Kadenskiy had taken these demands sufficiently into account he would not have taken such a simplified approach to the question of granite, would not have made errors in the evaluation of the processes of granitization and "degranitization," would have given the necessary attention to iron-magnesium-calcium metasomatism as a geologic phenomenon, and would not have produced a scheme not founded on factual material.

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Laboratory of Precambrian Geology
AN. S.S.S.R. Leningrad.

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SOME PROBLEMS OF METHODOLOGY IN PROSPECTING FOR PRIMARY DIAMOND DEPOSITS BY AERO METHODS

by

N. V. Kobets and B. V. Komarov

ABSTRACT

Methods of application of aero-surveys to the search for Kimberlite pipes are examined. The advantages of geophysical and aero-survey methods applied to complex investigations are discussed.

* * * * *

Primary diamond deposits have recently been discovered in Yakutiya.

A study of the ultrabasic rocks in which the first deposit was discovered established that these rocks are chemically, structurally, petrographically and mineralogically related to the kimberlites of South Africa [2]. These rocks also have been named kimberlites and the deposits are called kimberlite pipes or bodies.

Exploration for kimberlites was first accomplished by mineralogic surveys using the characteristic pyrope-ilmenite mineralogic association. Later, geophysical methods were successfully used (magnetic and aeromagnetic surveys).

At the same time attempts were made to use aerial surveys for this purpose. On an aerophotograph of scale 1:60,000, a pipe was noted as a round contour of darker shade by N.N. Sordarskiye and L.A. Popugayeva. This contour resulted from changes in the vegetation cover, related to the kimberlite outcrop. On the basis of this work a few dozen similar contours were selected and recommended for field investigation. However, further study confirmed that the contours were not kimberlite pipes; they resulted from other causes. This resulted in a skeptical approach to the possibility of using aero-survey methods in exploration for primary diamond deposits.

The chief causes of failure were lack of data for criteria of recognition of kimberlite pipes and the small scale of the photographs used.

In 1955, in the Laboratory of Aeromethods of the Academy of Sciences of the U.S.S.R., a study of the methods of prospecting for primary diamond locations using aerophotography was initiated by corresponding member N.G. Kell'. V.M. Barygina, in Yakutia, simultaneously began a small-scale investigation on aerophotography combined with field study. These investigations showed that with aerophotographs of scales 1:60,000 and 1:25,000 reliable deciphering of kimberlite pipes was difficult, since on such photographs it is easy to confuse them with other terrain elements. On the other hand, on large scale photographs -- 1:5,000 and 1:3,000 -- the pipe contours become diffuse. It was shown that for deciphering aerophotographs the best scales are 1:10,000 and 1:15,000; on these scales the contours corresponding to kimberlite pipes are seen most clearly.

In 1956 the Laboratory of Aero-methods carried out investigations in collaboration with the Eastern Expedition of the Western Geophysical Trust, Ministry of Geology and Conservation of Mineral Resources of the U.S.S.R.

In conjunction with the experiments on types of film and time of the day and year, the possibility of combining material from aerophoto and aeromagnetic surveys in kimberlite exploration was examined. This paper is primarily concerned with this question.

The region studied was north of the central Siberian mountain plateau. A sharply continental, hard climate, permafrost, comparatively simple geological structure and

monotonous relief characterize this area. This undulating plain covered with scattered Taiga type flora of daurskaya larch has quite an even relief, with rounded forms. More than half the region is occupied by valley slopes and inter-river areas. The essential factors controlling the relief are weathering by ice and solifluction. Above this plain is a small butte covered with trap forming sharp terraces which stand out on the aerophotographs.

The slopes are usually complicated by low structural-erosion terraces which are clearly marked by dense vegetation along the brows and by run-off ravines usually covered by green mosses. The elevations, however, have a light grey lichen cover.

This relief appears on the photograph as a characteristic series of strips of dark (terraces and ravines) and light tones (bases of terraces and inter-ravine elevations), distributed along and across the slopes (fig. 1). The sides of the valleys gradually merge into watershed surfaces without sharp changes in the landscape, with the exception of the uppermost parts of the watersheds, especially if these are covered by trap.

This area is composed of almost horizontal beds of carbonate rocks of lower Paleozoic age, in parts intruded by dikes and sills of trap, and kimberlite.

The insignificant monoclinic dip of the rocks to the southwest is complicated by weak plicative dislocations. This results from the proximity of the area to the edge of the northeastern boundary of the Tungusska syneclise of the Siberian platform. Disjunctive disturbances are also relatively weakly developed. Two distinct systems of rupture where trap rock occurs locally, are clearly marked in the aerophotographs: the northwestern and the north-northeastern

FIGURE 1. Aerophotograph characteristic of slopes covered with larch Taiga. Scale 1:15,000.

Y - structural-erosion terraces.
D - run-off ravines.

system.

The local peculiarities of geographic conditions and geologic structure, including the presence of kimberlite bodies and dikes of trap rock cutting the evenly-layered carbonate rocks, result in definite deviations from the above-mentioned general scheme of the structure and relief of the slopes. These deviations may appear as sharp breaks in structural erosion terraces, as changes in the general orientation of the run-off ravines, in the character of the vegetation, and in several other ways. For this reason, in prospecting for kimberlites just as in the explanation of other properties of geologic structure, it is necessary to analyze carefully the laws controlling the relief. Only in this way can deviations from the basic structure be fully explained. This method of analysis can be most satisfactorily accomplished by utilizing data from aerosurveys.

In the summer of 1956 the study area was completely covered by aerophotographs in the scale 1:15,000.

On deciphering the material, all known kimberlite bodies were seen and contours indicating the presence of other kimberlite bodies were observed. Various elements of the relief and geologic structure requiring field investigation were also noted. The deciphering was performed while bearing in mind the previously established attributes of the geologic structure of the region.

The contours were verified on the site by a team consisting of a geologist, geobotanist and an operational geophysicist, equipped with an M2 magnetometer.

The geobotanist studied vegetation on and around the contour area; the geophysicist determined magnetic field characteristics with the magnetometer; and the geologist examined the geological structure. This cooperation was very effective. Each of the specialists of the team was able to direct the work of the others and substantiate their data with his own. For instance, a high magnetic field in the area of the contour caused the geobotanist to study the vegetation more carefully and the geologist to plan the mining work with greater certainty.

During the field work three previously unknown kimberlite pipes were discovered.

Two of the three pipes are oriented in an east-northeast direction. Two more pipes discovered by other magnetic and structural survey expeditions are in a line with these. Not all the pipes are isometric in form. One of them 320 by 120 m strikes east-northeast (fig. 2). Thus, a logical supposition is that the given group of pipes are related to tectonic disturbances with resultant fractures oriented in this direction.

All the kimberlite bodies are distributed on forested slopes and watersheds of the sloping areas, and at times in stream beds. The thickness of the friable deposits in the first case may be insignificant (not more than 2.5 m) and therefore the kimberlite bodies buried under them can be detected from the character of vegetation and relief both in the field and on aerophotographs. Kimberlite bodies under a deeper layer of friable deposits do not show on the photographs.

An essential part is played by the depth of the permafrost, since the vegetation, one of the basic indicators of the properties of the geological structure (and the kimberlite bodies) reacts to changes in lithologic constitution only where the friable deposits lie above the permafrost layer. Consequently even if a thin layer of friable material is located near the surface of the permafrost layer, the character of the vegetation will not be influenced by rocks below this level, including the kimberlites.

As previously stated, recognition of kimberlites on aerophotographs depends on the character of the vegetation.[1]

In many instances the kimberlite bodies are associated with dense alder-larch forests on relatively rich soil. On the aerophotographs they appear darker and more even in tone than sparse Taiga growing on carbonate rocks. In the phase of full leaf development, this type of thick forest can be readily distinguished from the surrounding sparse tree country both on the site and on photographs. Consequently the identification of kimberlite bodies by vegetation is best accomplished by using aerophotographs taken at this time of year. In this region they were taken in July and the first half of August.

Thick vegetation, however, is characteristic not only of kimberlites, since similar areas occur on transported trap rock detritus. It also occurs on folds of watershed areas and on the brows of carbonaceous structural-erosion terraces. The character of the vegetation is determined by a number of factors favorable for growth, not only by geologic structure.

[1]In the present article the deciphering signs for kimberlite bodies are illustrated by material from field studies carried out mostly with photographs of a scale 1:15,000, using panchromatic aerofilm.

FIGURE 2. Kimberlite pipes. Scale 1:15,000.
1 - identified on the photograph by dense vegetation and destruction of the structural-erosional terraces, Y. 2 - recognized by the character of the vegetation.

All these properties must be taken into account in deciphering aerophotographs.

The form of kimberlite bodies is not a straightforward criterion for recognition. The outcrops of kimberlites vary in shape. Round and ring-shaped contours noted on aerophotograph can be related to: thermokarstic craters; stone circles overgrown with vegetation; horizontal beds of other rock types which have been eroded, especially on watersheds; eroded trap rock blocks; distribution of run-off ravines; vegetation; drainage conditions and others. Other criteria can also be used in the recognition of kimberlite bodies on aerophotographs. The kimberlites bodies, as a rule, are linear and interconnected in arrangement. This circumstance, which is probably explained by their location in zones of tectonic disturbance, draws special attention to the contours of suspected kimberlite bodies near known pipes. Moreover, disruption of the carbonaceous deposits (in the form of concentric circles) caused by penetration of kimberlite pipes can be observed. This criterion is especially important when the kimberlite bodies are small.

The weakening of the carbonate rock by tectonic activity and penetration by the less resistant kimberlites results in the activation of erosional processes. Negative forms of relief which are almost indistinguishable on aerophotographs are formed and the direction of the ravines is disrupted. The ravines bend continuously around the kimberlite body; this is apparently related to the presence of more stable rocks at the contact of the carbonate rock with the kimberlites. Sometimes the ravines adjacent to the kimberlite bodies seem to disappear and begin again on the slope beyond the kimberlites. This phenomenon can be explained by

the high permeability of the kimberlites.

More significant breaks in the relief, caused by the kimberlites, appear on the slopes. Here (in places where the kimberlites outcrop) the structural-erosion terraces cease and some lowering of the relief occurs; the kimberlites break down more readily, because of abundant fractures. This criterion is of special value where the kimberlite does not influence the vegetation (fig. 3). Thus, in no case can conclusions be based on aerophotographs alone. All the criteria discussed above must, however, be taken into consideration. Beginning with general laws of geomorphology and basic geologic structure, it is possible to identify on the aerophotographs brachifolds, disruptive displacements, dikes, and sills of trap rock in addition to kimberlite bodies. It is especially important to be able to identify small outcrops of trap rock occurring as local peaks in aeromagnetic surveys and represent "pipe" type anomalies.

Outcrops of trap rock are distinguished chiefly by their relation to particular forms of relief, resulting from their dense composition (fig. 4). The usually clear outline of the straight-line contours of trap rock outcrops, bounded sharply by ravines, and the dense vegetation associated with transported trap rock detritus, facilitate identification on aerophotographs.

On photographs of scale 1:15,000 a considerably greater number of elements of structure can be identified than on photographs of smaller scale. Geological and structural maps are more complete as a result and a more rational approach to kimberlite exploration is possible.

Thus, correct utilization of aerial survey data is extremely useful in kimberlite exploration. However, the efficiency is considerably improved if aerial survey data is used in conjunction with aeromagnetic survey data. The latter are not always sufficient for identification.

Aeromagnetic surveys for kimberlite bodies

FIGURE 3. Kimberlite pipes. Scale 1:15,000.

I - identified on the photograph by the characteristic destruction of the structural-erosional terrace Y.

FIGURE 4. Sill of trap rock (C). Scale 1:15,000.

are performed at a scale of 1:25,000. The magnetic fields created by ultrabasic rocks show up on the aeromagnetometer tape as anomalies. Large trap rock fields can be easily distinguished by their saw-shaped magnetogram. All the local magnetic anomalies resulting from the kimberlites and small trap rock formations are verified by field study according to data collected by V.E. Popova in 1956. This considerably complicates exploration.

By comparing maps of local magnetic anomalies with aerophotographs, anomalies which coincide with small sills and dikes of trap rock can be excluded immediately. These can be identified quite reliably on photographs.

The coincidence of local aeromagnetic anomalies with the contours of suspected kimberlites shown on the deciphered photoscheme considerably increases the probability of successful exploration and at the same time solves the question of the exact fixing of these anomalies. Aerophotographs simplify field exploration considerably. Usually, with aeromagnetic surveys this is accomplished with data from visual observations by a pilot, who notes orientations on the map. Later, after computing the results of the measurements, the anomalies are sketched into the map according to these orientations. In the randomly-orientated Taiga the positioning is approximated and, thus, field studies of anomalies are more difficult.

In the performance of an aeromagnetic survey the smaller kimberlite bodies, and those which are located between the route may be missed. In some localities actual routes, as a rule, deviate from the projected ones. These deviations are often as much as half of the distance between the planed routes and in aeromagnetic surveys in a scale of 1:25,000 kimberlite bodies of dimensions up to 200 to 300 m may be lost. The weakly magnetic kimberlite bodies can also easily be missed during interpretation of data from an aeromagnetic survey.

Kimberlite bodies missed by the aeromagnetic survey but which appear on the photographs, can be regained on deciphering data from the aerophoto survey. Kimberlite bodies not appearing for some reason or other on the aerophotographs may be disclosed by an aeromagnetic survey. Thus

these two methods support one another.

Comparison of material from aerosurveys with that from aeromagnetic surveys is considerably simplified if they are done simultaneously with the photography. As the work performed in the summer of 1956 by a team of geophysicists from the Laboratory of Aeromethods under N.D. Palitsyn has shown, this positioning can be best accomplished by using a narrow film, short focus camera of the cinecamera type and working continuously or intermittently, but synchronously with the magnetic channel of station ACGM-25. The picture on the small sized aerophotograph of the locality above which there is an increased magnetic field, coincides with the identical picture on the photoscheme. Thus the aeromagnetic anomaly is accurately fixed, even in the absence of any contour in the given location.

The combination of aerophotographic and aeromagnetic methods in kimberlite exploration does not exclude the necessity of mineralogical investigations, which help to distinguish the various diamond-bearing regions and serve as data for planning prospecting work by aeromethods.

Quite clearly, only the combined use of material from aerophotography, data from aeromagnetic surveys, and mineralogic tests can bring about a complete and correct solution of the problem.

Thus it is absolutely necessary to combine aerial photography with aeromagnetic work in the search for kimberlite bodies in regions similar to the one under discussion. Also, depending on the properties of the geologic structure and geographic conditions of the region, the importance of one or other of the methods will be correspondingly of greater or lesser importance, and will determine the method of study.

Such a combination of methods demands an organized effort of geologists and geophysicists who work disconnectedly at present. As experience from the described investigations has shown, it is necessary to coordinate the field work of the operational geophysicist and the geologist. By combining data from magnetic surveys and geologic investigations performed with high quality material from aerophotographs, the geologist can give the most correct interpretation to aeromagnetic survey data and decide on the necessity for further detailed work in a given region. In this way, kimberlite exploration is considerably facilitated.

In conclusion it should be noted that the material from aerophotographic and aeromagnetic surveys obtained in the search for diamond deposits can be used for prospecting for other useful minerals and even for geologic mapping and engineering surveys. This is all the more important since all the possible areas for diamond deposits known at present are found, as a rule, in regions of difficult accessibility or in sparsely inhabited regions of our country.

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Laboratory of Aeromethods,
Akademiya Nauk SSSR,
Leningrad.

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ON THE ORIGIN OF ELLIPSOIDAL LAVAS OF THE LOWER TUNGUSKA RIVER

by

V. I. Kudryashova

ABSTRACT

From a consideration of the mode of occurrence of the ellipsoidal lavas in the middle course of the lower Tunguska River and nature of the underlying rocks, the author concludes that the ellipsoidal structure of these lavas is due to cooling in an aqueous medium.

* * * * *

The problem of the origin of ellipsoidal lavas occurring in Siberian traps and containing most of the Iceland spar deposits is still unclear and debatable. G.G. Moor [7, 8] and A.V. Skropyshev [9] in their papers of 1945-1947, referred to them as "blocky lavas" and assumed that they were formed in the same way as the blocky "aa" lavas of Hawaii or the "apalkhraun" lavas of Iceland.

In recent years A.V. Skropyshev [10] changed his views on the origin of these structures. Referring to them now as "ellipsoidal volcanic agglomerates," he believes that they were formed as a result of eruption of clots of magma from volcanoes of the central type, which underwent subsequent hydrothermal alteration. In my opinion this view of the genesis of ellipsoidal lavas is without foundation. The new term "ellipsoidal volcanic agglomerate" appears to me to be basically incorrect, since the concepts "ellipsoidal" and "agglomerate" are contradictory and the word "volcanic" is unnecessary since the word "agglomerate" implies volcanic origin.

A.P. Lebedev's opinion of the origin of ellipsoidal lavas is different [3]. He admits the existence of typical ellipsoidal lavas among the Siberian lava flows, but considers them rare. He observed them only at the western end of the Suslov cliffs, where they are underlain by tuffs and have a spilitic aspect. These lavas, in his opinion, erupted in a nearshore environment. The greater part of the ellipsoidal lavas in the region between the mouths of the Kochechum and Nidym rivers along the Lower Tunguska River, he considers to be "rocks of the lapilli tuff type with volcanic bombs and accumulations of plastic lava material in various shapes and of the ellipsoidal lava type" ([3], p. 15). He notes that the "genesis of these tuffs is not quite clear" and suggests that the pancake-like inclusions of lava are large ejections of plastic lava contemporaneous with the ash.

My observations preclude acceptance of these solutions.

Ellipsoidal lavas are most common in the lower horizons of basaltic flows and usually occur as flattened lenses varying from 2 to 20 m in thickness and from 1.5 to 20 km in length. They have been found in the Lower Tunguska valley over a distance of 150 km, both below and above the village of Tur and along all the tributaries in this region, i.e., along the Turk, Kiryamka, Gonchak, Goncha and Viv' rivers.

The ellipsoidal lavas consist of rounded spheroidal blocks, spheres and elongated ellipsoids, usually flattened on the lower surface [fig. 1]. The "spheres" range from 0.5 to 2.0 m in diameter. Less commonly these bodies are larger, lens-like or pancake-like, measure 10 to 15 m along the longer axis and sometimes pass into bed-like structures (outcrops near the village of Tur on the right bank of the Lower Tunguska River).

The ellipsoidal lavas are composed of dense, aphanitic, glassy basalts or of fine-grained diabase. Outside they have a black to brown chilled crust, sometimes cinder-

like on the lower surface; inside they consist of concentric zones of small amygdules. The ellipsoids are broken by systems of radial and concentric joints (fig. 2).

FIGURE 1. Structure of spheroidal lava with accumulation of hydrothermal minerals (white).

The spheres and ellipsoids appear to be cemented with an aggregate of fragments of a dark-brown poorly crystallized vitrophyre, volcanic glass and an aggregate of chlorite, zeolites, calcite, quartz and other minerals (fig. 3).

The fragments of vitrophyre and glass are sharply angular, irregular and vary in size from 1 to 15 mm. The shape of the fragments gives the rock the appearance of agglomerate.

Accumulations of hydrothermal minerals are sometimes quite large, especially in the lower parts of the flows. Cavities 20 to 50 cm in diameter often contain large crystals of optical calcite (Iceland spar). Because of the high content of easily weathered minerals the agglomerate-like rocks break down rapidly into small fragments.

The relation between the dense blocks and agglomerate-like cementing mass is variable. In some areas the spheroidal blocks predominate, in others, the agglomerate-like cement.

The characteristic structural pecularity of the ellipsoidal lavas is an increase in the number of spheroidal blocks toward the roof of the flow and a decrease in hydrothermal minerals. Not infrequently the ellipsoidal structure is absent from the top part of the flow and the rock becomes massive with irregular blocky jointing; this is especially common in areas where flows are very thick. In rare cases the cementing material of ellipsoidal lavas contains ash (Viv' River).

FIGURE 2. Structure of a spheroidal block. The photograph shows the chilled crust, amygdules and radial joints.

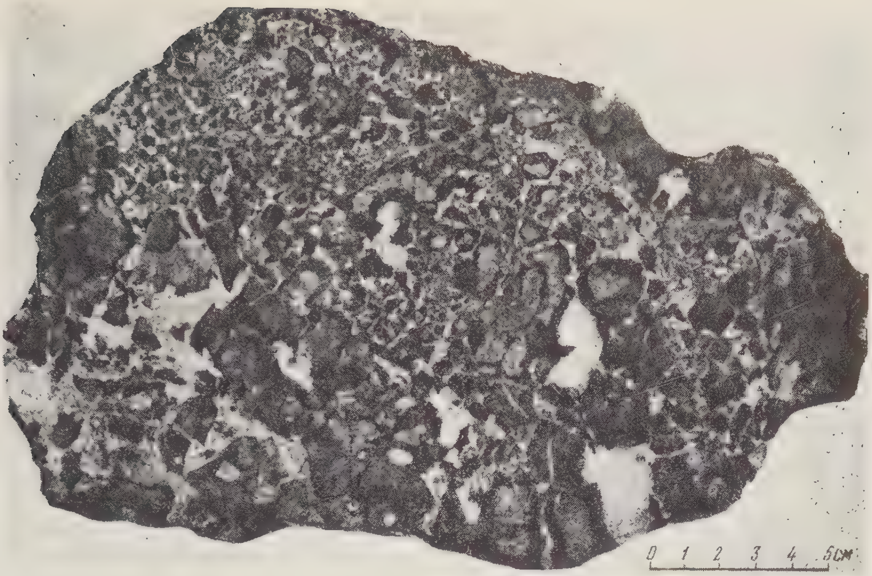

FIGURE 3. Structure of agglomerate-like interstitial rock. White--accumulation of hydrothermal minerals.

The structure and the mineralogy of these lavas do not give a unique answer to the problem of origin. When examining samples away from the field different geologists arrive at different hypotheses. Only an analysis of occurrence in the field and of the nature of the underlying rocks can result in the correct explanation of their origin.

The ellipsoidal lavas examined by the author have a flat lens-shaped form which in most cases is masked by poor exposure. In some localities, decrease in thickness at both ends of a flow can be clearly seen (right bank of the Viy' River, 45 km above its mouth; left bank of the Gonchak River, 10 km above its mouth, etc.). Elsewhere the thickness of the flow varies within a small distance because of the low wavy relief of the underlying rocks, as, for example, in the middle course of the Nidym River, where the thickness varies from 10 to 40 m within a distance of 10 km. Similar variation, but on a smaller scale, is observed on the Lower Tunguska River, 72 km above the village of Tur and on the Gonchak River (fig. 4, a).

On the left bank of the Gonchak River, 38 km from its mouth (left tributary of the Lower Tunguska), a small outcrop was found in which the typical ellipsoidal lavas, with a nest-like type of mineralization mostly near the lower surface, fill an eroded depression, a "basin" 5 meters deep and 20 meters long. The enclosing rock is basalt with columnar jointing (fig. 4, b). The contact between the two types of lava is sharp and irregular. In an exposure on the left bank of the Viv' River, 61 km above its mouth, the ellipsoidal lavas abut against tuffs with a curved contact (fig. 4, c). The cementing material of the ellipsoidal lava contains 50 to 60 percent ash. At an elevation of 5 to 6 m above the river the lavas contain horizontal layers of fine-grained agglomeratic tuff, 0.3 to 0.5 m thick, which lie concordantly with the enclosing tuff. All these factors suggest that the ellipsoidal lavas and tuffs in this area are contemporaneous.

The ellipsoidal lavas are usually underlain by tuffs. On the Nidym and Viv' rivers (above the Gil' tributary where the lowest stratigraphic horizons (flows) of the lava sequence are exposed, the underlying tuffs are repeated, alternating layers of different varieties, whose exposed thickness is 20 to 30 meters. The sections invariably begin with a thick bed of agglomeratic tuff containing large blocks of basalt, amygdaloid and other varieties of tuff and even some pumice. Higher in the section the size of the fragments in the agglomerate gradually diminishes and the rock becomes denser and has platy jointing. In the upper part of the sections the tuffs consist of thin alter-

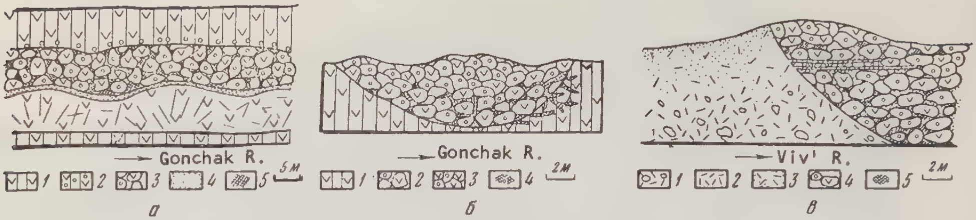

FIGURE 4. Types of occurrence of ellipsoidal lavas.

a) -- Left bank of the Gonchak River, 10 km from the mouth. The ellipsoidal lava lies on a low wavy surface. 1 - Basalt with columnar jointing; 2 - amygdaloid; 3 - ellipsoidal lava; 4 - tuff; 5 - accumulations of hydrothermal minerals.

b) -- Gonchak River, left bank, 38 km from the mouth. Ellipsoidal lava lying in an eroded depression in massive basalts with columnar jointing. 1 - Basalt with columnar jointing; 2 - ellipsoidal lava; 3 - amygdaloidal basalt with blocky jointing; 4 - accumulation of hydrothermal minerals.

c) -- Viv' River, left bank, 61 km from the mouth. Ellipsoidal lava lying in tuff. 1 - Tuff-breccia; 2 - agglomeratic tuff; 3 - fine-grained agglomerate tuff; 4 - ellipsoidal lava; 5 - accumulation of hydrothermal minerals.

nating beds of vari-colored (violet, green, olive-green and other colors) fine-grained tuffs and tuffaceous sediments. The bedding surfaces are often ripple-marked, have mud cracks and occasionally remains of plants and freshwater Estheria fauna. The tuffs in the lower part of the section often dip up to 60°, while in the upper part they flatten out and, judging by the platy jointing, become horizontal.

In the higher stratigraphic lava horizons, ellipsoidal lavas alternate with pahoehoe flows and are underlain, as a rule, by layers of homogeneous tuff and tuffaceous sediment from 10 cm to 1.5 m in thickness. Fragments of carbonaceous matter are frequently found in these layers. Such layers in association with ellipsoidal lavas may be observed in almost all exposures along the Lower Tunguska River and its tributaries (Gonchak River and others) although they are often concealed by talus.

The characteristic occurrence of spheroidal lavas, their localization in topographic depressions, which existed before their extrusion, the composition of the underlying rocks, tuffaceous shales and sandstones containing remains of freshwater fauna and flora and bearing ripple marks and mud cracks on their bedding surfaces all clearly indicates that the ellipsoidal lavas were formed in an aqueous environment. Most probably they were deposited in freshwater lakes and streams. There is no need to assume the existence of marine basins and there are no signs of them on the Lower Tunguska.

This is confirmed by the fact that the albitization of the plagioclase and chloritization of the dark minerals so characteristic of geosynclinal spilites are slight. In the latter, as noted by A.N. Zavaritskiy [1], "the transformation of normal basalts into spilites probably occurred as a result of interaction between the minerals of the basalts and sea water." Soda and silica necessary for the reaction were contributed partly by sea water and partly by the magma itself in the form of fumarolic gases dissolved in water. The excess silica gave rise to cherts and other siliceous sedimentary rocks intimately associated with spilites. Such phenomena are not possible in the continental environment of the platform. Here the most of the fumarolic gases escaped into the atmosphere and the rest were mixed with water vapors generated when lava flowed into a freshwater basin and formed saturated mineralized solutions. The latter, upon cooling, gave rise to low temperature minerals such as soda zeolites, calcite, silica and others.

It is possible that the basins and streams contained very small amounts of water, since in the thick flows the ellipsoidal structure and mineralized cavities are found mainly in the lower parts. Sometimes these features gradually disappear along the length of a flow.

The ellipsoidal lavas, or pillow lavas as

they are called in the literature, are widely distributed throughout the world. In 1914, Lewis [15] published a detailed compilation on pillow lavas of the world and came to the conclusion that the ellipsoidal (pillow) structure forms in lavas of intermediate and basic composition when they come in contact with marine or fresh water. The extrusion need not be subaqueous, but water from an outside source must participate in the cooling of the lava. In spite of a number of other hypotheses [16], most geologists hold Lewis' view. Stearns, in his studies of Hawaiian [18] and Idaho (Snake River) [17] lavas, notes that pillow structure is "found only where a supply of moisture was present in the form of vapor. . .;therefore the cause of this structure is either extrusion of lava into water or over moist ground or intrusion of lava into moist sediments."

Tyrrell [13], in his book on volcanoes, points out that in Iceland extrusions under torrential rain or under ice give similar pillow structures.

The typical spilitic ellipsoidal lavas are known from many regions of our country and from different sequences and have been described in considerable detail in the Russian literature. Proterozoic spilites of Karelia were described by F. Yu. Levinson-Lessing [4] and V.M. Timofeyev [12], those from the Kola Peninsula by N.I. Soustov [11], the Silurian spilites of the Urals were studied by V.A. Zavaritskiy [2], the Mugodzhar spilites, by Levinson-Lessing [5], and the Mesozoic spilites in the Kara Dag volcanic series of Crimea, by Levinson-Lessing and E.N. D'yakonova-Savel'yeva [6]. Spilites have been reported from Novaya Zemlya, Central Asia, the Altai and the Caucasus.

Ellipsoidal lavas described in the present paper have features in common with spilites (ellipsoidal structure) but differ from them in a number of respects, such as the absence of albitization and of association with siliceous and other marine sedimentary rocks. This resemblance, together with insufficient consideration of some other factors, such as the occurrence of the lavas and the composition of the underlying rocks, has led previous investigators to incorrect ideas concerning the origin of ellipsoidal lavas.

The facts briefly enumerated above indicate that flows of typical pillow lavas are rather widely distributed along the middle course of the Lower Tunguska River, especially in the lower part of the lava series, and represent a product of rapid cooling in water of lavas identical in composition and physical properties with those which form the enormously thick sequence of flows of the normal pahoehoe type. The exceptional enrichment of the ellipsoidal lavas in hydrothermal minerals which contain water, is also due to the cooling of lavas in the presence of external water.

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Institute of Economic Geology,
Petrography, Mineralogy and
Geochemistry, Acad. Sci. U.S.S.R.,
Moscow

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THE GENERAL ASSEMBLY OF THE INTERNATIONAL VOLCANOLOGICAL ASSOCIATION IN TORONTO (CANADA), SEPTEMBER 1957

by

A. P. Lebedev

From the third to the fourteenth of September, 1957, I participated in the meetings of the International Volcanological Association which took place in Toronto (Canada) as a part of the XI General Assembly of the International Union of Geodesy and Geophysics (I.U.G.G.).

The Volcanological Association has been in existence since 1919, but up to now Soviet volcanologists have taken almost no part in its work. During the 1954 Assembly in Rome, a Soviet representative, V.I. Vlodavets, attended for the first time and presented a general review of volcanological investigations in the U.S.S.R.

A considerable number of Soviet scientists representing different fields participated in the meetings of the Assembly at Toronto. The Soviet delegation included: Director of the Volcanological Laboratory of the Academy of Sciences, Professor V.I. Vlodavets (head of the delegation of volcanologists); Scientific Associates of the Volcanological Laboratory, B.I. Piyp, S.I. Naboko, G.S. Gorshkov, and V.G. Sil'nichenko; corresponding members of the Ukrainian Academy of Sciences, V.S. Sobolev (petrology) and Ye. K. Lazarenko (mineralogy); scientific associate of the Institute of Geological Sciences of the Armenian S.S.R., K.G. Shirinyan (volcanology); and scientific associate of the Institute of Ore Deposits, Petrography, Mineralogy and Geochemistry of the Academy of Sciences U.S.S.R., A.P. Lebedev (paleovolcanology, petrology).

The papers presented at the Assembly in Toronto were of considerable interest both as to number and variety. The cancellation of the originally projected excursion to the region of recent volcanism on the Pacific coast of Canada was compensated for, to a certain extent, by an excursion after the Assembly to the well-known Sudbury nickel deposit with its complex petrographic composition.

The Soviet delegation boarded a plane in Moscow on the morning of August 31 and reached Toronto on the evening of September 1, having flown over Stockholm, Prestwick, Keflavick (Iceland), Goose Bay (Labrador) and Montreal.

The meetings of the Assembly took place at the University of Toronto, one of the largest universities in Canada, occupying a number of buildings located in a large and beautiful park in the central part of town.

The auditorium of the Department of Mechanical Engineering, equipped for showing slides and motion pictures, was used for the meetings of the Assembly. The general meetings of the Congress took place in a vast graduation hall in a separate building (Convocation Hall). Our delegation was given a special hall in the main University building (Hart House) for an exhibit of Soviet literature on volcanology, petrology, and other subjects.

The work of the session took three directions, according to the program outlined during the preceding Assembly, and the following problems were discussed: a) modern volcanism, b) paleovolcanism, and c) geochronology. Below is a brief summary of the papers presented at the meetings which are likely to be of interest to Soviet readers. Many other papers were presented in written form and will be published some time in the future.

A long paper devoted to the problem of magma in relation to the internal structure of the earth's crust was read by the president of the Volcanological Association, Professor A. Rittman (Switzerland), one of the leading modern volcanologists, who is working at present at the University of Cairo (Egypt).

In Rittman's opinion the totality of geological and geophysical data leads to the following conclusions and definitions pertaining to the problem of magma.

Magma is a completely or partially molten silicate mass containing dissolved gases. It is present either within or directly under the solid crystalline crust of the earth and is capable of intruding into fractures and rising to the earth's surface; in the latter case it separates into lava and volcanic gases.

Using diagrams of state, Rittman arrives at the conclusion that relaxation of pressure is sufficient to produce completely molten magma from a material which is half molten, but that crystalline or glassy material cannot give rise to completely molten magma.

The source of basaltic magma, so widely represented in the products of terrestrial volcanism, is related to the existence of a continuous subcrustal layer of olivine basalt. Physicochemically this substratum is liquid, but because of high pressure it behaves like a solid.

Migma is a silicate mass existing within the earth's crust in a state of crystallization and containing intergranular solutions of pegmatitic composition capable of being injected into fractures. By analyzing equilibrium diagrams, Rittman explains the processes of anatexis, granitization and formation of gneisses and concludes that the melt formed by anatexis answers completely to the definition of magma.

The boundary surface corresponding to the Mohorovicic discontinuity sharply separates the layers of sial and sima, and the base of the earth's crust lies beneath this discontinuity and represents a transitional zone between crystalline (solid) and molten sima. The division of sial into upper (A) and lower (B) layers is partly due to magmatic differentiation. The rocks of layer A are products of granitization; those of layer B are products of degranitization. The boundary between layers A and B is sharp only in the orogenic regions; elsewhere it is not sharp or is absent (zone of undifferentiated sial AB). The average composition of the A layer is granitic to granodioritic and of the B layer, noritic.

These ideas on the relationship between crust and substratum agree with geophysical data and provide, in Rittman's opinion, a satisfactory explanation of the observed distribution of different types of magmatic rocks and metallogenetic provinces.

Rittman's paper called forth a lively discussion with important remarks and additions from Wedger (England), Macdonald (USA), Glangeaud and Geze (France), and others.

Rittman's second paper also was of considerable interest and dealt with the important paleovolcanological problem of the relation between deep submarine and subaerial volcanism. In Rittman's opinion, the differences between these two types of eruption must result in important differences in the mechanism of eruption and in the nature of its products. In deep submarine eruptions magmatic water contained in the magma spreading over the sea bottom has no way of escaping and is retained in the lavas, causing hydration of the solidifying lava (serpentinization, chloritization, uralitization, saussuritization). The volatile constituents of the magma become dissolved in sea water and later cause spilitization of lavas or change them into talc-magnesite rocks. This process explains the origin of the ophiolite series.

Deep-water (geosynclinal) volcanism is no less important than volcanism of the continental areas. It is probably active at present on the ocean bottom, especially in the great deeps. The primary magma here is olivine basalt which undergoes mainly gravitational differentiation as it rises. The resulting products (from plagioclase basalt to picrite) are extruded either during a single prolonged eruption or repeatedly from a series of separate centers.

There is no doubt that basaltic volcanism has been a most significant and frequent phenomenon in the history of the earth's crust and that an understanding of it is of great importance in the solution of geophysical problems. The explanation of this phenomenon is related to the characteristics of the structure of the crust and the substratum which were reviewed by Rittman in his first paper.

Rittman's third report dealt with a new chemical classification of igneous rocks. The basis of this classification is a formula computed from the weight percentages of oxides:

$$S = \frac{(Na2O) + (K2O)}{SiO2 - 43}.$$

For most volcanic series, S remains almost constant, but in other cases it changes gradually from femic to salic rocks. These variations in the magnitude of S are related to the process of magma evolution as indicated in Table 1 below.

On the basis of variation and magnitude of S and the ratios of alkalies, Rittman establishes rock series as shown in Table 2 below.

One of the most interesting papers on the problems of paleovolcanism and petrology of volcanic rocks was presented by Hisashi

TABLE 1.

Process	Variation in S	Variation in SiO_2
Gravitative crystallization differentiation	Constant or	Generally increases
Gaseous transfer in the upper part (+ alkalies)	Greatly increases	Remains constant or increases slightly
Gaseous transfer in the lower part (+ alkalies)	Decreases	Increases
Assimilation of sialic rocks including sediments	Decreases	Increases
Assimilation of magmatic rocks and limestones	Strongly increases	Decreases

TABLE 2.

S	Alkali ratio, %	General character of series
< 4	$Na_2O \lesseqgtr K_2O$	Pacific (calcic)
1 -- 1	"	Super calcic
1 -- 1.8	"	Calcic
1.8 -- 3	"	Calc-alkalic
3 -- 4	"	Subcalc-alkalic
> 4	$Na_2O > K_2O$	Atlantic (soda)
4 --	"	Subcalc-sodic
5 -- 7	"	Subsodic-calcic
7 -- 17	"	Sodic-calcic
17 -- (-6)	"	Sodic
(-6) -- 0	"	Super sodic
> 4	$Na_2O < K_2O$	Mediterranean (potassic)
4 -- 6	"	Subalkalic-calcic
6 -- 14	"	Potassic-calcic
14 to negative	"	Potassic

Kuno (Japan) on the "Origin of Cenozoic Petrographic Provinces of Japan and Surrounding Regions." The author distinguished three series of volcanic rocks differing chemically and mineralogically: 1) tholeiitic, 2) calc-alkalic and 3) alkalic.

The rocks of the Japanese Quaternary volcanoes along the Pacific coast and on the Marianas arc belong to the tholeiitic and calc-alkalic series; those of the volcanoes along the coast of the Sea of Japan, to the alkalic and alkalic-calcic series; the lavas of the volcanoes in the inner zone of the Japanese Islands, to the calc-alkalic series; and the rocks of Korean and Manchurian volcanoes, to the alkalic series. There are no sharp boundaries between the areas of distribution of these series.

Similar regularities of distribution are observed in Tertiary volcanic rocks.

In the region of the Marianas arc and Izu Islands the granitic substratum is absent and the thickness of the basaltic layer is not less than 20 km. Nearer to the Pacific coast of Japan a relatively thin granitic layer appears and increases in thickness under the Sea of Japan.

The primary tholeiitic magma was probably formed as a result of partial melting of peridotitic material in the upper part of the mantle below the Mohorovicic discontinuity. This magma poured out on the surface uncontaminated by granitic material and produced the rocks of the tholeiitic series. The primary magma of the alkalic olivine basalt series formed as a result of partial melting of the deeper parts of the peridotitic substratum. Although this magma did rise in the region of the Sea of Japan through a thick granitic layer, it did not assimilate granite, and produced rocks of the alkalic series. Only in the inner zone of the Japanese Islands where intensive orogeny occurred in mid-Tertiary times, both types of basaltic magma assimilated granitic and sedimentary material to a greater or less extent and built volcanoes composed of calc-alkalic rocks.

The regions of the earth's crust where magma is generated are, evidently, intimately connected with regions of intermediate and deep-focus earthquakes. Probably the two processes, the generation of magma and seismicity, have a common cause.

The interesting report by Mendons Dias (Spain) was devoted to the relation between tectonics and volcanism in the region of the Atlantic Ocean adjacent to the Azores. An analysis of the ocean bottom topography in the vicinity of the archipelago led the author to postulate tangential stresses in the subcrustal layer which acted in a southeast-northwest direction. These stresses caused folding and faulting and the latter initiated and localized volcanic activity. An analysis of deformations enabled the author to explain the sequence of eruptions for each of the volcanoes and for the archipelago as a whole.

Of especial interest was the paper by Macdonald, the former director of the Hawaii Volcanological Observatory, who spoke on "Protection against Lava Flows." For many years on the island of Hawaii defensive measures against lava flows from Mauna Loa have been sought, especially for the protection of the town of Hilo. At one time it was proposed that the lava flows be "exploded" by bombing from the air or by heavy artillery fire. It developed that this method is effective only under favorable conditions and cannot be used, for example, when lava advances through a narrow canyon or valley. Bombing or artillery barrage of such narrow targets is extremely difficult.

Another method, proposed by Jagger, is more effective. It consists in building walls along the predicted route of the flow in order to divert it to the side. The reliability of this method was checked in 1955. Walls may be built by piling up rocks, sand and even soil with a bulldozer so that the wall is at a sharp angle to the direction of flow. This is a rapid method of construction and walls may be built even in front of an advancing flow. Such walls serve as a protection against mud flows as well. It is important to note that for protection against more siliceous, and therefore more viscous lavas, stronger walls must be built.

The paper was illustrated by an excellent colored motion picture.

The Soviet scientists presented a number of papers, some of which were read at the Assembly meetings.

The papers by Soviet scientists not present at the meetings were submitted in written form (papers by G.D. Afanasyev, E.K. Ustiyeva, V.V. Ivanov). The abstracts of these and all other papers by Soviet scientists have already been published in part.[1]

G.S. Gorshkov's report on the "Gigantic Eruptions of the Volcano Bezymyannyy" gives a detailed description of the prolonged eruption of this Kamchatkan volcano, which began on October 22, 1955. A crater 700 to

[1] Abstracts of papers presented at the XI General Assembly of the International Volcanological Association, Acad. Sci. U.S.S.R., 1957.

800 m in diameter was first formed by explosions and then a plug was slowly pressed upwards. In March of 1956, a great explosion occurred accompanied by expulsion of hot ash. As a result of this explosion, the cone was lowered by 200 to 300 meters. The composition of the ash and lava is hypersthene and augite andesite. The total volume of erupted material is roughly estimated at 3 km^3. Numerous secondary fumaroles formed on the surface of an agglomeritic flow. This eruption was similar to the Katmai eruption of 1912. A study of its effects helps in understanding the pecularities of the Katmaian eruption.

The second report by Gorshkov was devoted to certain theoretical aspects of volcanism. Considering the absence of a direct record of transverse waves on the seismograms of the Kamchatka Volcanological Station from earthquakes in central and southern Japan, he came to the conclusion that this absence is due to the screening action of liquid magma in the region of the Klyuchevskiy volcano. Knowing the distance to the volcano and having determined the angle of emergence of waves at the surface, the author determined that the magmatic chamber lies at a depth of 50 to 60 km, i.e., approximately at the boundary between the crust and the mantle. From this he deduced that at that depth the rocks are in a condition particularly favorable to melting due to sudden changes in physical conditions. Gorshkov also presented a number of other conclusions of a general nature concerning the depth of magmatic chambers and the causes of eruptions.

The paper by V.I. Vlodavets on the problems of volcanic structure at depth was based on the data obtained during the 1938 eruption of the Klyuchevskiy volcano. In his opinion the adventive cones of a volcano must be directly connected with the deep-seated magmatic chamber (and not with the main vent of the volcano). This conclusion is based on a study of the evolution of lavas from adventive craters which changed gradually from basic to acid.

The paper by S.I. Naboko on the "Emanations of Certain Kamchatka-Kurile Volcanoes and the Products of Their Reaction with the Atmosphere, Water and Rocks" also was devoted to modern volcanism. On the basis of his study of a number of eruptions, the author concluded that all eruptive magmas contain basically the same volatile constituents and that the composition of emanations at any given period depends on the phase of activity and the stage of crystallization of lavas. In the early stages the emanations from the Klyuchevskiy volcano contained all volatile constituents. As the cooling advanced, the content of the halides diminished first, then sulfurous gases and finally carbon oxides. The composition of thermal waters also is related to the physical condition of the magma and depends on the temperature and depth at which condensation and solution of gases in meteoric waters take place. The character of hydrothermal solutions determines, in its turn, the character of post-volcanic alteration of rocks. As a result, a re-grouping of elements occurs in the rocks, and some elements are dispersed while others are concentrated.

A number of papers by the Soviet scientists dealt with problems of paleovolcanism.

A.P. Lebedev's paper, "The Tungus Paleovolcanic Formation," presented the history of Upper Paleozoic-Lower Mesozoic volcanism which created the vast Siberian basaltic province in the western part of the Siberian platform. The earlier stages of volcanism were violent eruptions which deposited enormous amounts of ash over the Tungus depression. Fissure eruptions of basalt, which formed flows and hypabyssal bodies, such as dikes, veins, sills, stocks and laccoliths, occurred later. The history of the formation as a whole is characterized by the long duration of volcanic activity and the multitude of eruptions occurring against a background of slow oscillatory movements of the platform. The periodic extrusion of almost undifferentiated basaltic magma in the upper structural zone of the platform favors the hypothesis of periodic generation of magma in the substratum underlying it. At the same time, certain local differences in the composition of the rocks of the formation and the hydrothermal manifestations observable in individual areas of the Siberian platform speak for the existence of differences in the composition of the basaltic substratum itself and possibly in favor of the existence of intermediate magma chambers.

In a short addition to Lebedev's paper, V.S. Sobolev briefly characterized the relatively young ultrabasic volcanic manifestations recently discovered on the Siberian platform (the kimberlites of Yakutia).

K.G. Shirinyan presented a paper on the "Basic Features of Recent Volcanism in Armenia." The recent volcanic activity in Armenia occurred in a region of great tectonic complexity which, according to structural geologists, consists of individual rigid consolidated areas separated by intermontane synclines. The centers of intensive manifestation of subaerial volcanism were localized at the boundaries of different structures and in the updomed parts of the rigid areas. Armenian volcanoes are of the fissure Strombolian, Hawaiian and Vulcanian types.

Many reports on geochronology were presented, devoted both to techniques and to the determination of absolute age of individual formations. Detailed summaries of these reports will be published in the Bulletin of the Committee for Determination of the Absolute Age of Geological Formations, Acad. Sci. U.S.S.R.

Considerable time was devoted at the Assembly to the problem of reorganization of the Volcanological Association. The question of changing the name of the Association and reorganizing its internal structure was raised at the meeting of the Executive Committee of the Geodetic and Geophysical Union in April of 1956. At that time a desire to broaden the Association's field of activity and renaming it the Association of Volcanology, Composition of the Earth and Geochronology was expressed. After a lively discussion, it was decided to retain the name of the Association, but to broaden its field of activity. This resulted in the formation within the Association of the following sections: 1) Active Volcanism, 2) Vulcanophysics, 3) Physical Chemistry of Magmas and 4) Paleovolcanism and Plutonism. At the concluding meeting the following officers of the Association were elected: president, Professor A. Rittman (Switzerland); vice-president, J. Schairer (USA); general secretary, F. Signore (Italy); president of the section of active volcanism, M. Neumann van Padang (Holland); of the section of volcanophysics, G.S. Gorshkov (U.S.S.R.); of the section of physical chemistry of magma, H. Kuno (Japan); and of the section of paleovolcanism and plutonism, B. Geze (France). In his concluding address the President expressed a desire to strengthen the Association's activity, to encourage exchange of information, personal contacts and excursions into regions of active volcanism.

During the sessions the government of Ontario arranged a reception for the delegates. Soviet delegates were given an opportunity to visit the Museum of Geology and Mineralogy in Toronto and the Geological Survey of Canada in Ottawa.

After the end of the sessions, some of the delegates, including V.I. Vlodavets and the author, took part in an excursion to the Sudbury nickel deposit. The delegates examined the interesting magmatic complex of Sudbury which encloses the nickel deposit. The igneous body is a lopolith lying almost horizontally in the Precambrian schists of the Grenville series. The lower part of the body is composed of norite; the upper, of micropegmatite. There are also dikes and veins of diabase and diorite. The mineralization, as is becoming apparent now, is related genetically to this younger phase in the development of the structure.

The meetings of the Assembly were of great scientific interest. They contributed considerably to the establishment of scientific and personal contacts among scientists of different countries working in the broad field of volcanology.

NEW DATA ON THE OCCURRENCE OF BITUMENS IN THE CAMBRIAN ROCKS OF SOUTHERN FERGANA

by

B. V. Yaskovich

The Cambrian rocks of Southern Tien Shan have been little studied and their distribution is not completely known. Up to 1955, outcrops were known in the village of Shodymir, along the Aravan and Isfairam rivers, in the Kyzyl-Kungei Range, in the northern Nura Tau, in the western part of the Turkestan Range and in the region of the Sulyukt Mine [1].

Except for the belt of Cambrian rocks in the Turkestan Range, all of these exposures are isolated, tectonically enclosed remnants. Some investigators supposed that the thickness of Cambrian rocks is small and that they do not play an important role in the geological structure of the region.

In 1955-1956, as a result of investigations by the Uzbek Geological Administration, it was established that the outcrops of Cambrian rocks occur in erosional windows and reveal parts of a single thick series. For example, in one area, the thickness of the Middle Cambrian strata alone exceeds 2,500 m.

In the villages of Shodymir and Madygeya, where the bitumen-bearing Cambrian rocks were studied, Cambrian strata can be traced for about 20 km from the Sary Tag mountains in the east to the Chaar mountains in the west [2]; the thickness of the series is not less than 3,000 m. The rocks are exposed in topographical depressions and in deep creek valleys where the overlying formations have been removed by erosion.

The characteristic feature of the Cambrian rocks of the region is the dominance of sandstones and siltstones. The latter frequently consist of alternating argillaceous, arenaceous-argillaceous, siliceous and other marine sediments. Among the sandstones and shales there are beds of tuffaceous sandstones and flows of basic lavas, mainly spilites and basalts. In these rocks are numerous lenses of limestones, frequently bituminous and filled with fossils of brachiopods, gastropods and pteropods.

Besides the well-known Middle Cambrian fauna from Shodymir, the Cambrian rocks (Sagul, Sauk-tan'ga and Kashumkuyu creeks) also contain the following fossils identified by N.P. Suvorova, O.K. Poletayeva and O.N. Andreyeva: Kootenia sp. Bonnia sp. 1; Bonnia sp. 2; Binodaspis sp. ind.; Olenoides sp. Olenoides inexpectans Lerm.; Agnostus sp.; Clavagnostus sp. ind.; Cotalagnostus sp. ind.; Solenopleura paula Suv.; S. ferganensis modesta sub. sp. Suv.; S. praestabilis Suv.; Acrotreta sp.; Nisusia sp.; and Mututella sp., which are characteristic of the Middle Cambrian and the upper horizons of the Lower Cambrian.

The bituminous Cambrian rocks of Southern Fergana are widespread. The lenses of dark limestone are especially rich in light fractions and give off a strong odor of benzine on heating. Bituminous sandstones are also common. Bitumens occur throughout great thicknesses of sandstone and are localized in horizons having specific lithological features.

Bituminous rocks on Sauk-tan'ga Creek and in the village of Shodymir, where samples were taken, are found in beds containing numerous Middle Cambrian fossils of the kinds listed above.

Samples for luminescence tests were taken from argillaceous bituminous sandstone and brecciated bituminous siliceous rocks. The argillaceous sandstone is massive. It consists of poorly rounded grains of quartz, siliceous lithic fragments, and occasional muscovite. The sizes of grains range from 0.01 to 0.1 mm. The cement is argillaceous and is strongly colored by brown bitumen. Loss on ignition is 11 percent.

The siliceous, chert-like brecciated rock consists of a fine-grained siliceous mass with grain size ranging from 0.005 to 0.05 mm. The intersticial spaces are filled with black, opaque bitumen. Loss on ignition is 11 percent (tables 1 and 2).

No. of sample	Name of rock	Color of luminescence under ultra-violet rays	Effect of chloroform	Color after chloroform treatment	Color during evaporation of chloro-form	Nature of bitu-men	Texture	Amount of bitu-men, percent
1.	Argillaceous sandstone (Sauk-tan'ga)	Brown	Positive	Greenish-yellow	Brown	Inter-mediate bitumen A	Selec-tively satu-rated	0.709
2.	Siliceous rock (Shodymir)	Brown		Milky-yellow	Yellowish-brown	Inter-mediate bitumen A	Selec-tively satu-rated	1.42
3.	Siliceous brec-cia (Sauk-tan'-ga)	Brownish-gray		Bluish-white	Yellowish-brown	Oil-rich bitu-men A	Spotted	0.36
4.	Conglomerate with accumula-tions of bitu-men	Yellowish-orange and brown		Whitish-yellow	Yellowish brown	Inter-mediate bitumen A	Selec-tively satu-rated	6.25

TABLE 2. Chemical Analysis of Bitumen According to the Coal Laboratory, Acad. Sci. Uzb.S.S.R.

Locality of Sample	C	H	N	S
Bitumen from Cambrian rocks Sauk-tan'ga (half-liquid)	81.5	10.2	0.27	0.85

The siliceous breccia is composed of angular fragments of chert-like rock ranging in size from 0.5 to 3.5 mm. The fragments are cemented with brown opaque bitumen with an admixture of hydrous amorphous material.

Signs of migration of petroleum in the form of accumulations of half-liquid bitumen were found also in the Lower Carboniferous conglomerates overlying Cambrian strata.

Our data show that the bitumen-bearing rocks contain free bitumen A of the petroleum series. Judging by the color of luminescence of chloroform treated samples, the bitumens from the Cambrian rocks belong to the group of light oils.

The considerable bitumen content in the Cambrian formations suggests that some of their horizons are petroliferous.

The data cited above point to the need for further investigation of the bituminous Cambrian rocks of Southern Fergana, which may result in a change of opinion concerning the possibility of petroleum occurrence in this region.

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Uzbek Geological Administration,
Tashkent

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THE COMPOSITION AND STRUCTURE OF DUMORTIERITE

by

D. P. Serdyuchenko

1. During the past three years two very interesting papers on dumortierites from the region of Kutna Hora have been published in Prague. These papers, by F. Fiala [11] and J. Losert [14], not only present new data on the geology and mineralogy of this locality but also give an important review of almost all known foreign dumortierite occurrences together with a detailed summary of optical, x-ray diffraction and thermal data on this boron-bearing mineral.

According to the descriptions of both authors, the dumortierite of the Kutna Hora region (65 km southeast of Prague) occurs in pegmatites cutting biotite-muscovite paragneisses, quartz gneisses and quartzites, pyroxene gneisses, hornfelses containing garnet, pyroxene, epidote, clinozoisite and schists with magnetite, graphite, micas, kyanite and sillimanite. All these rocks are strongly migmatized and the quartz-feldspar injection bands contain red-violet fibers of dumortierite, schorlite, apatite, muscovite, arsenopyrite, kyanite, garnet and graphite as accessories. In the central parts of the zoned pegmatites are large prismatic crystals of dumortierite up to 5 cm in length associated with quartz, potash feldspar, oligoclase, schorlite, indicolite and, less commonly, kyanite, muscovite, garnet, arsenopyrite and apatite. The same pegmatites carry fibrous second generation dumortierite which, together with quartz, forms fibrolite-like (felted) aggregates in the spaces between other minerals. Similar fibrous aggregates of dumortierite in parallel intergrowth with sillimanite needles and prisms of kyanite replaced by fine scales of pyrophyllite have been described from an Arizona locality [21].

Fiala and Losert consider that the presence of dumortierite in the pegmatites and migmatites of Kutna Hora is due to the excess of alumina assimilated from paragneisses and paraschists containing kyanite. The association of dumortierite with andalusite, sillimanite, kyanite, cordierite and corundum in other pegmatites is also explained by assimilation of alumina, but Losert admits the possibility of initial excess of alumina in the pegmatite melts. The dumortierite from Miscovice, according to its paragenesis, is considered by Fiala as an "occurrence of the primary type associated with Al-B pegmatites developed in schists, especially among migmatized paragneisses."

However, the authors do not discuss and clearly define the source of boron, the essential component of dumortierite, considering it, apparently, as a magmatic product which has no genetic connection with paraschists and paragneisses containing "dumortierite-bearing" granites, pegmatites, aplites and quartz veins. This concept seems to us insufficiently substantiated and debatable, and therefore we shall discuss the question of the original source of boron in dumortierite schists, migmatites and pegmatites in some detail.

Moreover, the chemical analyses of dumortierite from Kutna Hora given by Fiala and Losert differ considerably, and it is necessary, therefore, to discuss the composition and chemical constitution of dumortierites in general.

2. In some Arizona localities there are large deposits of Precambrian dumortierite schists in which the boron mineral is intimately associated with andalusite, kyanite, sillimanite and pyrophyllite. These schists are a part of a complex containing chlorite and quartz-sericite schists [21].

Characteristic parageneses in the dumortierite rocks of North America were noted long ago by Schaller [18]:

Arizona -- dumortierite, quartz, muscovite, kyanite;

California -- dumortierite, quartz, muscovite, sillimanite;

Washington -- dumortierite, quartz,

muscovite, andalusite.

Very large deposits of dumortierite schists are known also from the vicinity of Rochester, Nevada [15].

For the California locality (a quartz vein of "undoubted igneous origin" in a decomposed biotite granite), Schaller assumed a late introduction of boric acid from the magma which, cooling slowly under pressure, caused partial alteration of sillimanite into dumortierite.

The origin of dumortierite itself and the associated andalusite, sillimanite, cordierite and garnet in the topaz-tourmaline-monazite-beryl pegmatites (Copacavapa, near Rio de Janeiro, Brazil) and also in topaz aplites and the autometamorphic granites (Krimitzberg, Saxony) were considered by Riman [17] and Reuscher [20], respectively, as a result of assimilation of enclosing alumina-rich rocks by pegmatites and aplites.

3. In all of these cases, the authors, recognizing the sedimentary-metamorphic or assimilation (at the expense of enclosing rocks) origin of the alumina-rich minerals (andalusite, kyanite, sillimanite and others), relate the existence of dumortierite to an introduction of boron from magma.

However, according to the data of Goldschmidt and Peters [13] and of A. Ye. Fersman [10], the content of boron in sea water and in marine clays is 15 times as great as in the earth's crust and 150 times as great as its average content in plutonic (igneous) rocks.

In salt deposits, boron is concentrated, not in the rock salt beds and other evaporites, but almost exclusively in the insoluble residues and thin clay partings [9].

It is known that argillaceous sediments can adsorb considerable amounts of alumina during the process of sedimentation [3], and in high temperature metamorphism this may lead, of course, to the formation of acicular dumortierite crystals in the metamorphosed sediments.

Unfortunately, even now many investigators are still bound to the tradition connecting the presence of boron in metamorphic rocks with magmatic sources (without sufficient reason but automatically!).

The possibility of capture of boron from the invaded sedimentary rocks, its assimilation and transfer (in pneumatolytic-hydrothermal solutions) by igneous rocks, and particularly by granites, is often neglected.

During the intrusion of pegmatites and aplites and in injection metamorphism, favorable conditions often arise for the concentration in tourmaline, kornerupine, dumortierite and other boron minerals of boron previously dispersed (adsorbed, endocryptic, in isomorphous admixtures) in the sedimentary rocks and paraschists [6, 7].

The author is inclined to believe that not only the Arizona but also the Czechoslovakian (Kutna Hora) and many other dumortierites are related to syngenetic boron concentrations in strongly argillaceous sediments and that not only Al_2O_3 but also B_2O_3 from these rocks was assimilated by intruding aplite and pegmatite at the time when the thermodynamic and geochemical conditions necessary for the crystallization of dumortierite existed in the zone of migmatization, just as aluminous but not boron-bearing sediments in the metamorphic zone give rise to sillimanite gneisses and schists.

In a number of cases, dumortierite in ancient metamorphic rocks enters also into quartzites formed at the expense of argillaceous quartzose sandstones. Dumortierite in strongly pleochroic aggregates (N_p -- violet-rose, $N_m = N_g$ -- pale blue) intergrown with acicular sillimanite is found in roughly banded sillimanite-tourmaline quartzites (containing a little feldspar) in the sequence overlying the ore-bearing beds in the Fedorov formation of the Iyengra Archean series in the Tayezhny region, the iron deposit on the Aldan River (South Yakutia).

The mineral is elongated parallel to Np, has parallel extinction, forms polysynthetic twins with (110) as the twinning plane and geniculated twins with angles of nearly 120°. It is notable that dumortierite occurs in the Taezhny deposit in those areas of sillimanite-tourmaline quartzite where prismatic grains of metamorphic tourmaline are partially resorbed and replaced by an aggregate of acicular sillimanite. Evidently the boron for the dumortierite was obtained from tourmaline during its decomposition and partial replacement by sillimanite.

Acicular dumortierite occurs also in a fine-grained quartzite in the Balaghat region (India) in association with sillimanite, tourmaline, rutile and apatite [16]. It has distinct (100) cleavage and very strong pleochroism: N -- cobalt blue, $N_m = N_g$ -- pale blue or colorless; it is optically negative with $2V = 29°$ (-); $Ng = 1.705 \pm$ $Np = 1.685 \pm$. The axial plane is parallel to (100).

4. The chemical composition of dumortierite in many cases fits very well into the empirical formula derived by Schaller [18]: $8Al_2O_3 \cdot B_2O_3 \cdot H_2O \cdot 6SiO_2$. However, a

number of analyses of this mineral given in the literature deviate considerably or strongly from this formula, as can be seen from Table 1.

TABLE 1. Chemical analyses of dumortierites from different localities.

	1		2		3		4		5	
Components	% wt.	Mol. p.	% wt.	Mol. p.	% wt.	Mol. p.	% wt.	Mol. p.	% wt.	Mol. p.
SiO_2	30.28	505	28.81	480	28.68	478	29.86	498	28.49	475
TiO_2	0.08	1	0.20	2	1.45	18	---	---	---	---
Al_2O_3	60.30	591	63.46	622	63.31	621	63.56	623	64.58	633
Fe_2O_3	1.49	9	0.65	4	0.23	1	0.23	1	---	---
FeO	0.71	10	---	---	---	---	---	---	---	---
MnO	0.03	---	---	---	---	---	---	---	---	---
MgO	0.63	16	0.22	5	---	---	---	---	---	---
CaO	0.91	16	---	---	---	---	---	---	---	---
Na_2O		---	---	---	---	---	---	---	---	---
K_2O	"	---	---	---	---	---	---	---	---	---
B_2O_3	5.18	74	5.12	73	5.37	77	5.26	75	5.51	79
H_2O	1.27	70	1.38	77	1.52	84	1.41	78	1.42	79
Total	100.88	99	99.84		100.56		100.32		100.00	

1. Kutna Hora, Kuklik, Analysis by J. Losert [14].
2. Kutna Hora, Miskovice, Analysis by Z. Patsal, 1954 [11].
3. California, Analysis by Schaller [18]. Average of two very close analyses.
4. Arizona, Analysis by Ford [12]. Average of three very close analyses.
5. Theoretical composition: $8Al_2O_3 \cdot B_2O_3 \cdot 6SiO_2 \cdot H_2O$.

Losert drew attention to the fact that his analysis showed significant amounts of FeO, MgO and CaO in dumortierite which did not appear in the older analyses of the mineral, but which cannot be neglected. This investigator does not elucidate the role of R''O in the chemical composition of dumortierite, and it is necessary, therefore, to recall that:

a) The chemical composition and crystal structure of dumortierite are undoubtedly derived from sillimanite, i.e., $Al_{12}Si_4O_{20}$ (sillimanite) -- $Al_8[Si_3B](OH)O_{19}$ (dumortierite), with one SiO_4-tetrahedron replaced by a $BO_3(OH)$ tetrahedron.

b) In the sillimanite structure in the chains of AlO_6 octahedra stretching parallel to the crystallographic c-axis, each octahedron shares two oxygens with its neighbors and the chains are united by independent (nesosilicate) SiO_4, $BO_3(OH)$ and AlO_4 tetrahedron (see model of sillimanite structure

n Makhachki [4] and Belov [1]);

c) The structure of sillimanite differs from hat of andalusite but has some features in ommon with it, such as the mica-like groups Al_4^{VI} $(Al_4^{IV}$ $Si_3B)$ (OH) O_{19} + KOH + $9H_2O$ = $(OH)_2$ Al_2^{VI} (Al Si_3O_{10}) + + 5Al $(OH)_3$ + H_3BO_3;

d) The R"O oxides which enter into some umortierites replace Al^{VI} according to the cheme $R_3 \rightarrow Al_2$ just as in manganous anda-usites (containing not Mn_2O_3 but MnO up to bout 11 percent by weight); Mn_3 substitutes or Al_2 [5].

For these reasons the recalculation of the hemical analyses of dumortierite is made ere by expressing R'' in equivalents of R'''.

The molecular ratios of the main constit-ents are:

Analysis	R_2O_3	B_2O_3	SiO_2	H_2O
1	8.17	1	6.82	0.95
2	8.57	1	6.57	1.05
3	8.10	1	6.21	1.09
4	8.26	1	6.60	1.05

he structural formulas of dumortierite cal-ulated for 19.5 oxygen ions (on "dry" mate-al) with the subsequent determination of e number of (OH) groups are as follows:

$[(Si_{3.20}\,B_{0.80})(B_{0.14}\,Al_{3.78})]^{7.92}\,Al_{4.00}^{VI}$

$(OH)_{0.88}\,O_{19.06}$

$[(Si_{3.07}\,B_{0.93})\,Al_{4.00}]^{8.00}\,Al_{4.00}^{VI}$

$(OH)_{0.93}\,O_{19.07}$

$[(Si_{3.05}\,B_{0.95})\,(B_{0.03}\,Al_{3.97})]^{8.00}$

$Al_{4.00}^{VI}\,(OH)_{1.00}\,O_{19.00}$

$[(Si_{3.13}\,B_{0.87})\,(B_{0.08}\,Al_{3.85})]^{7.93}$

$Al_{4.00}^{VI}\,(OH)_{1.00}O_{19.00}$

Schaller [18] wrote: "It is perfectly natu-l that Al_2O_3, B_2O_3 and H_2O are found in umortierite in definite (numerical) ratios," e., the mineral is not chemically variable ith Al_2O_3 - B_2O_3 or B - F - OH isomor-ism) and the variations in its composition e due to inaccuracies of analyses or npurities in the sample.

This statement is still true to some ex-nt, but an examination of two new analyses (pure) dumortierites from Czechoslovakia d reliable (repeated) analyses of the min-al from North American material indicate that:

a) The empirical ratio Al_2O_3 : B_2O_3 : SiO_2 : H_2O more or less approximates 8 : 1 : 6 : 1 but very seldom corresponds to it exactly, due to slight but definite varia-tions in the relative content of Si, B and Al in the tetrahedral groups, i.e., in the silli-manite structure these elements are isomor-phous Si_{IV} - B_{IV} - Al_{IV}, the main replace-ment being that of silicon by boron accom-panied by a compensational replacement of oxygen by hydroxyl; here boron is in four-fold coordination and the vertices of its tetrahedron hold three oxygen and one hydroxyl ions;

b) The aluminum-oxygen octahedral chains have a stable composition but admit to a small degree (according to present data) the isomorphous substitution of Al^{VI} by Fe''' and R'' (the $R''_3 \rightarrow Al_2$ type of substitution);

c) The structural formula of dumortierite [Al_4 $(Al_4BSi_3O_{19}OH)$?] proposed by Strunz [19] takes the substitutions Si - B Al^{VI} into consideration and must be considered correct;

d) If the bivalent cations which occasionally enter into the composition of dumortierite are considered, the complete formula of dumor-tierite must be written in the form $(R''', R''_{3/2})_4$ $[Al_4BSi_3O_{19}(OH)]$.

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Council for the Study of
Productive Resources,
Academy of Sciences U.S.S.R., Moscow

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ON THE DISTRIBUTION OF CLASTICS IN THE GOTLANDIAN AND DEVONIAN OF THE TUVA DOWNWARP

by

I. M. Varentsov

In the history of the development of every large structural region, a definite connection may be observed between the rocks and the stages of tectonic development. This connection has been established for platforms and folded geosynclinal areas in general. But the evolution of every given region is usually characterized by a series of individual, specific features whose investigation is a substantial part of the study of formations.

Without reviewing the history of the formation of the Tuva downwarp and without analyzing the formations developed within it, we shall attempt here to generalize the data on its Gotlandian-Devonian clastics and reveal the basic regularities of their vertical and horizontal distribution. The multicomponent vector diagram of arenaceous sediments is of great help in this kind of work [2].

It should be pointed out that the Gotlandian and Devonian sediments, which play an important role in the upper part of the Tuvan structure, belong to the fairly complex molasse facies such as usually develops in the final stage of the geosynclinal cycle. This facies contains 85 to 90 percent detrital material, and provides a clue to the parent rocks which have undergone erosion.

The Tuva downwarp was formed in the Gotlandian age. The threefold subdivision of the Gotlandian group (the lower, Llandoverian stage is represented by a sand-conglomerate sequence; the middle, Wenlockian, by limestones and shales; and the upper, Ludlovian, by red sandstones) corresponds to the structure of the transgressive cycle. The Llandoverian sand-conglomerate sequence lies with a strong angular and erosional unconformity on Precambrian, Cambrian and Ordovician strata. It is difficult to estimate the length of time during which these strata were emergent, because, in most cases, the Gotlandian sediments lie with erosional unconformity on different Cambrian horizons. It may be noted that the Llandoverian conglomerates (pebble and boulder) are rather widely distributed in the regions of uplift with a relatively stable tectonic regime (the areas adjacent to the Central Tuva uplift, the slopes of the Eastern Tannu-Ola Range and the regions of the northeastern structural zone).

In the southwestern regions of the downwarp, arenaceous rocks predominate among the sediments. The Llandoverian conglomerates and sandstones are mainly of the graywacke type, among which tuffaceous graywackes, graywackes, quartz-graywackes and, to some extent, feldspathic graywackes predominate. The parent rocks from which these sediments were derived were, evidently, Cambrian, Precambrian and, in part, Ordovician siliceous shales, cherts and acid volcanics, together with the ultrabasic, gabbroid and granitic rocks intruded into them. The considerable thickness -- 200 to 2,000 m, poor sorting of the fragments, crude stratification, frequent massive cross-bedding and a rather weak lateral persistence suggest, first of all, that the sediments accumulated in a basin with a mobile, rapidly subsiding bottom at a time when the surrounding land had a complexly dissected relief. The specific composition of the parent rocks, mainly siliceous shales and volcanics, and the rapid accumulation of clastic material buried without much reworking, produced the Llandoverian graywackes. It is well known that graywackes are formed, in general, in the early stages of the existence of downwarps (mainly geosynclinal) when metamorphic basement rocks are exposed in the zone of denudation.

The Wenlockian age in the history of the Tuva downwarp was the time of maximum marine transgression, with embayments of the sea reaching into the marginal parts of the Eastern Tuva uplands at the base of the Eastern Tannu-Ola Range, i.e., into stable areas consolidated during the older orogenic phases (Early Caledonian). Clastic rocks play a subordinate role among the Wenlockian limestones and shales. They are mainly feldspathic-quartzose sandstones, quartz-

graywackes, arkosic sandstones and siltstones. The sediments of this age accumulated in a shallow marine basin bordered by a land of gentle, probably somewhat peneplaned relief. In this setting, in a warm humid climate, the greater part of the unstable clastic constituents was decomposed and erosion of exposed large acid and intermediate intrusives determined, to some extent, the arkosic, feldspathic-quartzose and quartz-graywacke composition of the terrigenous sediments.

During the Ludlowian age the Gotland sea retreated and continental-lagoonal red and variegated sands and silts were deposited. The predominance of red arkosic feldspathic-quartzose sandstones and quartz-graywackes, often with fine curved cross-bedding, ripple marks and mud cracks, indicates that these sediments were deposited in an arid climate in shallow basins and small lagoons remaining after the retreat of the sea. It is important to point out that Gotlandian sediments always contain tuffaceous and pyroclastic material. In the Llandoverian rudites it is represented by crystal and lithic acid pyroclastics with a small admixture of ash; in the finer-grained Wenlockian sediments, on the contrary, much fine ash is often found dispersed in the limestones and argillites. The centers of eruption lay, evidently, on the continent (Eastern Tannu-Ola Range, Western Sayan Mountains and Eastern Tuvian upland). During the Ludlowian age, the character of volcanic material changed considerably, for besides the pyroclastic material some geologists [3] have recorded lava flows of acid and, more rarely, intermediate composition in the upper horizons of these deposits.

The Lower Devonian clastics are mainly tuffaceous quartz graywackes and feldspathic graywackes. The volcanic activity initiated in the Ludlowian age reached its maximum in the Lower Devonian with a very irregular distribution of volcanic vents. In the relatively stable regions of the central and northeastern zones of the downwarp there were many flows of basic, intermediate and, less frequently, acid lavas, accompanied by intensive ejections of pyroclasts. In the southwestern regions of the downwarp, volcanism reached its culmination at the end of the Lower Devonian. The sedimentary components, mixed in various proportions with pyroclasts, were deposited as thick, red, less commonly, gray and variegated beds in shallow, freshened, drying-up basins. The abundance of local sources of sediments and the rapid burial of clastic material without any noticeable reworking during transportation and deposition produced the rather complex volcanic and tuffaceous graywacke deposits.

The clastics deposited during Eifelian age are distinguished by variety and a definite distribution in the downwarp [1]. This is explained by the sharp environmental boundaries existing at this time and by the preservation of the earlier (Gotlandian-Lower Devonian) structural plan of the downwarp. Within the boundaries of the southwestern facies-structural zone the terrigenous sediments proper have a limited distribution; but in the abundant limestones, merlstones and similar sediments there are frequently large amounts of siliceous pyroclastic material. On the margins of the southwestern region of the zone there are thick rhyolite and andesite flows containing layers of ash and agglomeritic tuff.

In the central zone of the downwarp the Eifelian clastics are very similar to those of the Lower Devonian. They are mainly tuffaceous quartz graywackes and feldspar graywackes. Volcanic activity was weakening at this time, for lava flows of basaltic and intermediate composition occur only in the lower parts of the section. Thick red sandstones were deposited in a freshened shallow lagoon and in the subaqueous parts of a foredelta (second half of Eifel). In the northeastern structural zone coarse-grained alluvial sandstones and conglomerates were deposited. Their composition reflects mainly the character of the older rocks of the bordering continent. The two lower sequences are tuffaceous and arkosic; the upper one is tuffaceous graywacke. This change in composition of terrigenous sediments indicates that at the beginning of the Eifelian age the underlying Lower Devonian, mainly effusive rocks were eroded. Then, with the deepening of the erosional surface, Ordovician, Cambrian and Proterozoic rocks were affected.

The Zhivetian terrigenous sediments are notably varied, but their main constituents are tuffaceous-arkosic rocks. Not uncommon among these sediments are feldspathic-quartzose sandstones, quartz graywackes and feldspathic graywackes. The variety in the composition of tuffaceous sedimentary rocks is explained, apparently, by the fact that they accumulated in a shallow brackish lagoon during a rather rapid subsidence. Subaqueous alluvial fans often formed in the lagoon and a part of the sediments underwent repeated redeposition. It must be borne in mind that the structural plan of the downwarp during the Zivetian age was essentially the same as during the Eifelian age and that the main sources of volcanic-terrigenous material were still in existence.

It is appropriate to point out that the change in the composition of the arenites in the southwestern zone was rhythmically

discontinuous and occurred only during short periods of geologic time as a result of sharp lithological and facies changes. The latter were due to the shallow-water lagoonal environment of deposition and to a rather complex differential movement of the blocks constituting the bottom of the basin of sedimentation. The Zhivetian tuffaceous-arkosic sandstones of the region of the Tuz Tag salt mines (southwestern zone) and the similar rocks from the village of Bai Balun and Kyzyl Dzhara (central zone) show this particularly well.

The composition of the Upper Devonian clastics, like that of the Zhivetian, is rather complex and varied; but unlike the Zhivetian clastics, the Upper Devonian sandstones from different regions of the southwestern zone and from other parts of the downwarp differ considerably in composition. The terrigenous sediments from the vicinity of the village of Sagly are tuffaceous graywackes, the sandstones from the middle course of the Kham-Dyt River are tuffaceous arkoses, in the region of the Tuz Tag salt mines there are tuffaceous-arkosic and, less commonly, tuffaceous feldspathic graywackes, and in the region of the village of Bai Bulun, tuffaceous quartz graywackes and feldspathic graywackes are widespread. The notable feature of the composition of most Upper Devonian clastics is the presence of fine-grained lithic fragments of argillites, siltstones, marlstones and limestones characteristic of the Upper Devonian and Zhivetian deposits.

These rocks represent alluvial-alluvial fan facies and not infrequently lacustrine-lagoonal facies deposited during rapid subsidence. Under these conditions, rather complex polymict sediments were formed and buried rapidly without much reworking. The main sources of the clastics were the older (Cambrian and Ordovician) basement rocks and local uplifts composed of Upper and Middle Devonian rocks. During Upper Devonian time, volcanic activity became much weaker. The main eruptive centers were located in the extreme southwestern parts of the downwarp adjacent to the Mongolian Altai and Gorny Altai mountains, but there were also subordinate vents within the boundaries of the Early Caledonian massifs (Western Sayan, Eastern Tannu Ola, Eastern Tuva Upland, etc.).

In summary, the following main points concerning the composition and distribution of the Gotlandian and Devonian terrigenous rocks may be emphasized:

1. The thick Gotlandian and Devonian series fill the middle Upper Paleozoic synclinal Tuva downwarp. By tracing the change in the composition and structure of these sediments areally and in section, it is possible to follow the evolution of the structure.

2. The Gotlandian and Devonian rocks are represented, in the overwhelming majority of cases, by tuffaceous arkosic sandstones and graywackes.

a) The accumulation of feldspathic-quartzose, arkosic and quartz graywackes occurred during the time of rather slow subsidence of the basin of sedimentation bordered by a more or less peneplaned or slightly dissected land. Under these conditions, clastic material was subjected only to the initial stage of reworking. This consisted in the removal of the unstable components during the erosion of parent rocks and reworking of the terrigenous material during transportation and deposition.

b) The accumulation of different varieties of graywacke and especially of true graywacke and feldspathic graywacke occurred during a rapid subsidence when the land was rather strongly dissected and ancient Paleozoic metamorphics were undergoing erosion.

3. During Gotlandian and Devonian times the main phases of volcanic activity in the Tuva downwarp occurred in the Ludlowian age, the Lower Devonian epoch and the first half of the Eifelian age. Within the boundaries of the southwestern regions of the downwarp, volcanism continued up to the Lower Carboniferous time. Elsewhere in the downwarp the effects of volcanic activity were reflected in the deposition of tuffs and in tuffaceous admixtures in the sediments.

4. During each geological epoch or age of the time interval under consideration, the distribution of clastic material occurred in general according to the structural plan and tectonic regime of the downwarp: a) the thicknesses increase regularly from northeast to southwest; b) the grain size and silica content of the terrigenous sediments increase in that direction; c) the content of volcanic clastic components also increases in the same direction as well as the content of fragments of metamorphic, sedimentary and, less frequently, volcanic rocks. The latter feature is due to the rapid burial of clastic material during rapid subsidence; d) the degree of metamorphism of the rocks under discussion increases noticeably towards the southwestern boundaries of the downwarp. While in the central and northeastern parts of the downwarp argillaceous sediments, the most sensitive to the changes in pressure and temperature, are represented mainly by compacted hydromica-bearing argillites, in the region of the village of Sagly these sediments have undergone regional metamorphism and have been changed into

sericite-chlorite, quartz-sericite and quartz-epidote schists. In the arenaceous rocks metamorphism is manifested by the appearance of granoblastic texture and the development of secondary siliceous and feldspathic cements and authigenic epidote feldspar, hematite and magnetite.

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Geological Institute,
Academy of Sciences U.S.S.R.,
Moscow

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ON THE METHOD OF CORRELATION OF THE LOWER PERMIAN SECTIONS OF THE DONBAS, ITS NORTHWESTERN MARGINS AND THE EASTERN PART OF THE DNIEPER-DONETS DEPRESSION

by

L. P. Nesterenko

Permian deposits of the southern part of the Russian platform are most completely represented in the northwestern part of the Donbas, where they are exposed in the large Bakhmut basin. Here they have been studied in detail and serve as the type section for correlating numerous borehole sections within the Donbas, on its margins and to the west of it in the Dnieper-Donets depression.

Considerable difficulty, however, arises in the correlation of Permian beds of these regions because of the absence of sufficient paleontological data.

Recently a number of attempts have been made to correlate the Permian beds of the eastern part of the Dnieper-Donets depression and the Donbas [1, 2, 4], but since the new data on Permian stratigraphy of the Donbas [3, 5, 6], which substantially modify the accepted ideas about these sediments, were not used, these correlations are of doubtful value.

In the past, lithology was the basis for separation of individual formations in the Donbas, but it is known now that even within the exposed part of the basin the sediments exhibit considerable facies changes. Therefore, the lithological approach has become unacceptable for the subdivision of Permian sediments. The author has already presented a new stratigraphic scheme based on the discovery in the Permian sequence of key marine horizons, mainly limestones, which preserve their characteristic features over long distances [6].

This stratigraphic scheme is based on a detailed study of the Lower Permian strata in the exposed part of the Donbas. It has been discovered that in spite of a number of facies changes the framework of the key beds established in the eastern part of the Bakhmut basin retains its usefulness in the concealed northwestern margin of the Donbas and in the eastern part of the Dnieper-Donets depression. Moreover, many of the key beds preserve, at least in part, those individual lithological and paleontological features which they possess in the open part of the Donbas.

For this reason a detailed study of the Lower Permian section of the Donbas, and in particular of the characteristics of individual key beds as well as of the nature and direction of facies changes of the entire sequence, makes it possible to make reliable correlations of these sediments with the corresponding sediments of the western margin of the Donbas and the eastern part of the Dnieper-Donets depression.

In confirmation of this, a number of facts will be cited following the description of stratigraphic sequence.

The Upper Paleozoic copper-bearing sandstones of the Donbas were considered in the past to be a uniform redbed (variegated) formation. Our investigations have shown that this formation undergoes a number of facies changes within the open part of the basin and that, therefore, the old criterion for its identification is incorrect [5, 6]. The key beds which have been discovered in this formation, together with the facies changes, make it necessary to correlate these sediments by selecting key horizons such as the Araucarites formation in the lower part of the section and the higher limestone-dolomite formation. This is confirmed by the author's analysis of a section of the Upper Paleozoic rocks penetrated by a number of boreholes in the vicinity of the village of Torsk, where, because of the presence in the section of limestone horizons of the Araucarites and limestone-dolomite formations and of the typical "gray zones" of the copper-bearing sandstone formation, it was possible to correlate borehole sections with the sediments of the exposed part of the Donbas. It should be noted that in this part of the Donbas limestone horizons begin to appear in the lower, and especially, the upper parts of the copper-bearing sandstones which formerly were referred to the adjacent formations.

Farther west and northwest there are fewer data on the copper-bearing sandstones. Still, the presence in them of limestone beds in the northwestern margin of the Donbas, which extend, probably, to the eastern part of the Dnieper-Donets depression, may solve the problem of facies changes in this formation and establish its equivalènce to the well-known sediments of the Bakhmut basin.

The principle key beds in the overlying limestone-dolomite formation are limestones and dolomites R_1, R_2, R_3, and R_4. They lie in the lower part of the formation, mainly among gray arenaceous-argillaceous sediments which contain layers of gypsum (and anhydrite). The upper part of the formation is a thick sequence of argillites often containing casts and molds of a marine fauna. In the middle of this sequence there are several sandstone beds (sometimes up to 20 m thick). This argillite sequence is very characteristic of the formation and is evidently quite extensive areally. It can be easily traced in the exposed part of the Donbas and serves as a key bed. Farther to the northwest it has been found in boreholes in the regions of the villages of Torsk and Drobyshev and still farther, at Izyum (near Spevakovka). The same sequence was probably penetrated by the drill in the Balakleev region (Shebelinka). The underlying limestone and dolomite key beds are known from the Torsk and Drobyshev regions and farther west and northwest.

The salt-bearing formation in the open part of the Donbas contains four key limestones: the "copper-bearing" limestone, S_1; the "chalk-like" limestone, S_2; the "folded" limestone, S_3; and the "pelecypod" limestone, S_4.[1] The "copper-bearing" and the "pelecypod" limestones are thin (up to 1 m) and are sometimes hard to find in the section. But the "chalk-like" and "folded" limestones are thick (5 to 10 m and more) and are usually easily seen. A special place in the section of the salt formation and of all the Lower Permian sections is occupied by the "folded" limestone, which, because of its thickness, structure and a characteristic and persistent fauna, is one of the best key beds widely distributed not only in the western part of the Donbas but beyond it.

To the northwest of the open part of the Donets basin, those horizons, which preserve their lithological and paleontological characteristics, have been found by the author in a group of boreholes near the village of Torsk and farther, near the village of Drobyshevo. It is interesting that here the thick Nadbryantsevsk and Bryantsevsk salt beds, which occur on the eastern limb of the Bakhmut basin, are absent, but the Karfagensk salt beds become quite thick.

In the region of Izyum (near Spevakovka) the salt beds have recently been penetrated by a number of boreholes. The key beds of the eastern limb of the Bakhmut basin are present in them. Moreover, the foraminifers and facies characteristics of the limestones studied by G.D. Kireyeva indicates that the individual characteristics of the main limestone key beds are largely preserved, and especially well, in the "folded" and "pelecypod" limestones.

Still farther northwest, in the Balakleyev region, within the boundaries of the eastern margin of the Dnieper-Donets depression, the salt-bearing formation was penetrated by numerous deep boreholes during the exploration of the Shebelinsk gas deposit. Here, evidently, the entire key bed framework of the salt formation of the Donbas is preserved. Inadequate cores and absence of records of the borehole sections make our method inapplicable and the presence of all the key beds cannot be established in these boreholes. A study of samples and thin sections of a number of limestones penetrated by the boreholes showed quite definitely the presence of the "folded" and "pelecypod" limestones and thus made it possible to correlate these sediments with the sediments of the eastern limb of the Bakhmut basin. The "folded" and "pelecypod" limestones of the Shebelinsk gas deposit were also identified by Kireyeva, who has made detailed faunal and lithologic studies of the key beds in the Bakhmut basin.

Thus, the data cited above indicate that the key beds, mainly limestones, which serve as the framework for the stratigraphy of the Donbas are widely distributed beyond the region where they were first discovered. They should be used (together, of course, with a general analysis of the section) as the basis for correlation of the sediments of the open Donbas with the corresponding sediments of its western margins and of the eastern part of the Dnieper-Donets depression. It can be supposed that in the tracing of the Lower Permian beds farther to the west (even over intervals of 50 to 100 km) the established key bed framework will retain its usefulness and in detailed stratigraphic studies will permit correct correlation of sections in spite of various facies changes. This is confirmed by the fact that in the Permian sediments found in the vicinity of Chernigov, Kireyeva identified both the "folded" and the "pelecypod" limestones by their characteristic features. It follows from this that the Chernigov formation, separated here by F.E. Lapchik, probably

[1]The characteristics of these limestones are given in the author's work 6 .

corresponds essentially to the salt formation of the Donbas and not to the limestone-dolomite formation as was believed by Lapchik [4].

In light of what has been said, the subdivision of the Lower Permian deposits of the northwestern margin of the Donbas and of the eastern part of the Dnieper-Donets depression and their correlation with the sediments of the open part of the Donbas exclusively on the basis of lithological uniformity of certain formations or their members loses meaning and may lead to grave errors.

Let us cite, for example, a recently published work by a group of authors [1] in which an attempt is made to correlate the salt formation of the Balakleyev region (Shebelinka) with the salt-bearing sediments of the eastern part of the Bakhmut basin. Subdividing the sediments into separate sequences (horizons) [1] on lithological grounds, the authors of the paper correlate them, again by lithological characteristics alone, with the salt-bearing sediments of the Bakhmut basin (using N.N. Yakovlev's subdivision of the latter). As a result, the authors make the mistake of referring the "lower salt-bearing horizon" to the Podbryantsevsk salt bed. But their section contains "folded" limestone which lies in the "upper anhydrite horizon" and for which they give an extensive list of foraminifera [1]. Inasmuch as the "folded" limestone lies at the base of the Bryantsevsk salt bed, the underlying "upper salt-bearing horizon" must correspond either to the Podbryantsevsk bed or, together with the "lower salt-bearing horizon," to the Karfagensk salt beds, as it does in the region of Drobyshev. To solve this problem it is necessary to establish the position of the "chalk-like" limestone, which lies either in the "upper anhydrite horizon" or in the "middle anhydrite horizon."

It is evident from this discussion that there is no basis for the authors' conclusion that the salt-bearing beds of the Bakhmut basin and the Balakeyev region were deposited under generally persistent physical and geographical conditions and that the Balakeyev section is more complete.

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[1] The term "horizon" is very inappropriate in this case, for according to the authors its thickness reaches 430 m [1].

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The N.S. Khrushchev Donets
Industrial Institute
Stalino

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CONCERNING L. N. BOTVINKINA'S PAPER ON "TRANSGRESSIVE AND REGRESSIVE SERIES OF FACIES IN COAL-BEARING STRATA"[1]

by

D. P. Filippov

L.N. Botvinkina discusses the question of transgressive and regressive series of facies in coal-bearing strata. She comes to the conclusion that in the Middle Carboniferous coal-bearing sediments of the Donets basin "the sequence of facies of the regressive part of the cycle differs from that of the transgressive part even though the entire cycle was formed under the same paleographic conditions" (p. 60). Further, the author writes: "Facies may be divided into groups according to two principles: 1) paleographically, by considering the character of the facies which depend on proximity to land and depth of water in the basin (marine, gulf, lagoon and continental facies) and 2) by the position in the transgressive or regressive phase. The transgressive phase is characteristic of the part of the sedimentary cycle overlying the coal; the regressive series, of the part underlying the coal. Sometimes sediments of the same facies are found in both phases but such cases are not typical" (Ibid.; underscoring mine. D.F.)

The conclusion concerning the difference between the facies of the regressive and transgressive parts of the cycle due to change in the direction of oscillation of the earth's crust is illustrated by a diagram (fig. 5, p. 53) showing that regressive and transgressive facies in the same zone of sedimentation are different and that this difference does not depend on particular physical and geographical conditions but holds for all types of facies.

The present author has studied the Middle Carboniferous coal-bearing sediments in the northeastern part of the Donets basin (Kamenskiy, Belokalitvenskiy and Tatsinskiy regions) for many years and paid special attention to the productive formation C_2^4 which has almost no coal in the central and western parts of the basin but becomes the most important productive formation in the northeastern part of the Donets basin where it contains industrially valuable beds of bituminous and coking coal.

In studying the conditions of sedimentation and coal accumulation we used the method of cyclothem-facies analysis proposed and formulated by Yu. A. Zhemchuzhnikov in a number of well-known works and also the suggestions given in the "Atlas of Lithogenetic Types of Middle Carfoniferous Sediments of the Donets Basin," compiled by a group of associates of the Geological Institute of the Academy of Sciences, U.S.S.R., in 1956.

The abundant material in our possession does not allow us to agree entirely with L.N. Botvinkina's conclusions in the paper under discussion. While there is a small difference in the facies of the regressive and transgressive parts of the cycle in the Middle Carboniferous coal-bearing sediments of the Donets basin, it is observed only in continental or transitional sediments, i.e., in sediments strongly influenced by land. In marine deposits there is no difference between the facies of the regressive and transgressive parts of the cycle, and Botvinkina's series of facies for the regressive and transgressive parts of the cycle for different marine zones do not correspond to reality. For example, in the Tatsinskiy coal region, in the formation C_2^4, which here is 500 m thick, we separated fifteen marine and nearshore cyclothems, ranging from 18 to 70 m in thickness, which contain up to nine coal beds, and in all of them, both in the regressive (beneath the coal) and in transgressive (above the coal), parts analogous to marine and littoral facies are found.

The basic difference in facies between the regressive and transgressive parts of the cycle lies, first, in a decrease in thickness of the transgressive marine and nearshore sediments which causes an asymmetry of structure of the cyclothems in relation to coal, and, second, in the character of the sequence of deposition of these facies deter-

[1] Izvestiya, Akademiya Nauk SSR, Ser. Geol., no. 2, 1956.

ained by the difference in the direction of he oscillatory movements of the basin bottom nd the adjacent areas of the land.

It has been established for formation C_2^4, which has been studied in detail, that the ransition from marine to continental (swamp) acies and vice-versa always occurs through n interfingering silty facies deposited in the one of wave action in the nearshore shal- ows. This facies appears in the section as characteristic banded siltstone composed f coarse light-grey silt (fine sand) and ark-grey, medium-grained and fine-grained ilt and sometimes argillite. The stratifica- on in this group of rocks is complex, a ombination of ripple marked laminae and ross-bedding with frequent truncations of e beds. In the regressive part of the ycle (beneath the coal), the interfingering ilts gradually pass upwards in the section to coarse silt and fine sand brought to the a by streams and often serving as the ase for the development of continental eposits including peat bogs. In the trans- essive part of the cycle (above the coal) e coal beds are usually overlain by the ayey-silty facies of lagoons and gulfs hich, as the land was lowered and the sea vanced, was again covered by interfinger- g silts of the zone of wave action in the arshore shallows. Since subsidence was ster than uplift the thickness of these silts the transgressive part of the cycle is ually less than in the regressive part.

The mineralogical and petrographic studies the silts from the regressive and trans- essive parts of the cycle in thin sections d by immersion showed no difference tween them. The same is true of marine ts and clays which were deposited farther om shore in a deeper marine environment. ese sediments, like the interfingering ts, participate in the structure of the gressive and transgressive parts of the cle and are lithollogically alike in both ses but thinner in the transgressive part the cycle. Petrographic studies of marine ts and argillites and thermal and chemical alyses of clays from both parts of the cle also showed that there is no difference ween sediments from the regressive and nsgressive parts of the cycle.

Botvinkina explains the difference between sediments of the regressive and trans- essive series of facies from the coal- aring strata by saying that during regres- n "sedimentation proceeds at the expense material coming directly from land. The umulation of sediments and tectonic vements act in the same direction, rais- the bottom of the sea and thus creating ditions for changing the facies from rine to continental." (p. 55). During the formation of the transgressive series, "the leading role is played by subsidence, by a tectonic factor. Sedimentation proceeds mainly at the expense of material <u>originating in the sea or completely reworked by it.</u>" (p. 56. Underscoring mine. D.F.)

Botvinkina's idea that in the formation of the coal-bearing strata of the Donets basin, materials derived from the land were deposited during regressions, while materials originating in the sea or reworked by it were deposited during transgressions, is, in our opinion, artificial and unconfirmed by facts.

It is generally known that the coal-bearing strata of the Donets basin, with the exception of thin limestone beds and coals, consist of terrigenous sands, silts and clays, which took part in the formation of both regressive and transgressive parts of the cyclothems. Therefore, no deposition of material originating in the sea could have occurred during the transgressive phases. As for reworking of terrigenous material by the sea during the deposition of the coal-bearing strata of the Donets basin, it occurred during both regressions and transgressions, as indicated by the similarity of structural and textural features of the terrigenous sediments and by the absence of differences in mineralogical and petrographical composition of these rocks from the regressive and transgressive parts of the cyclothems.

Thus, the additional subdivision of facies recommended by Botvinkina according to their position in the transgressive or regressive part of the cyclothem, in addition to the generally accepted subdivision into marine, transitional and continental facies, is unfounded, unnecessary and conducive only to complication and confusion in the application of the cyclothem-facies method to the study of coal-bearing strata.

In conclusion, it should be noted that Botvinkina arrived at her conclusion as to the difference between regressive and transgressive facies formed in the same paleogeographic environment on the basis of study of sections in the open part of the Donets basin (Dolzhanskiy and other regions). The present author, on the other hand, has studied sections from the largely concealed northeastern part of the Bol'shoy Donbass (Tatsinskiy coal region). However, as shown by the facies-lithological analysis, the same paralic environment existed during the deposition of the Middle Carboniferous sediments in the latter part of the Donets basin as in the open Donbass.

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GEOLOGIC LITERATURE OF THE U. S. S. R.

by

I. I. Ginzburg

The All-Union geological library VSEGEI has issued a "Bibliographical Annual of the U. S. S. R." for 1951, 1952 and 1953 and "Geological Literature of the U. S. S. R." for 1955 (4 issues). Unfortunately there are still no bibliographies for 1954 and for a part of 1955.

These publications are enthusiastically greeted by every geologist. It is enough to point out that according to these reference books, 2, 862 papers in geology were published in 1951, 5, 352 in 1952 and 1953, and just two issues, 4 and 5 for 1956, list 3, 472 works. It is obvious that no geologist can read all the literature on the subject which interests him, even that published here, let alone that published abroad. Publication of bibliographic guides therefore fills a real need in geological research and is very useful and essential.

The periodic issuance of bibliographies is especially to be commended, since it makes it possible to learn the date of their publication in advance.

The material of the "Bibliographic Annual" is divided into eleven sections subdivided into groups according to the branches of geology or regions. In the 1951 and 1952-1953 issues there is a subject index which, unfortunately is lacking in the 1956 issue.

The useful undertaking of the All-Union geologic library VSEGEI should be enlarged and a bibliography of geological works published under the 40 years of the Soviet regime should be compiled in at least four issues by decades.

This is much needed, for the lack of such a bibliography makes our work more difficult and often results in duplication of research. A bibliography covering forty years would make it possible to find the necessary material and to avoid duplication and old errors. Unfortunately, old geologists have lost the habit of using bibliographies and the young ones have not learned to use them, because so few bibliographies are available. As bibliographies become a necessity to a geologist, like any other reference work, the need will become greater of organizing an All-Union geologic library center, from which not only a research worker but any practicing geologist can borrow the needed book or article found by him in the bibliography, or have it copied.

In every distant corner of our vast land every geologist should be aware of the published works in his field and have the opportunity to obtain them. Geological bibliographic annuals should be helpful in accomplishing this.

ABOUT THE BOOK: "IRON ORES"[1]

by

I. I. Ginzburg

The Institute of Scientific and Technical Information, the A.A. Baykov Institute of Metallurgy and the Permanent Inter-Departmental Committee on Iron have issued a [illegible]1-page bibliography of works on iron ores. The number of entries is 10,557 and the compilation took 17 years.

The bibliography lists all literature on iron ores which appeared in our country from the time of introduction of the printing press through 1954 and includes not only published works but also a number of unpublished manuscripts and abstracts preserved [illegible] 879 different institutes, libraries, foundations, card indexes, etc.

The bibliography consists of three sections: 1) geology of iron ore deposits (scientific editor, G.A. Sokolov), 407 pp., 5,076 annotated works; 2) exploitation of iron ore deposits in the USSR and abroad (scientific editor, Academician A.M. Terpigorev), [illegible]0 pp., 3,072 annotated entries; 3) beneficiation and dressing of iron ores (scientific editor, V.T. Dergach), 132 pp., 2,409 annotated entries. The section on "geology" is the largest and consists of a general section on the problems of geology of iron deposits (64 pp.) and a special section on iron deposits of the USSR grouped according to regions. The brief annotations accompanying each geological entry give, according to the nature of the work, the composition of the ores, occurrence and reserves, enumerate individual deposits and give resumes of the most interesting parts of the work.

The second division consists of two parts devoted to 1) organization and economics of iron industry in the U.S.S.R. and 2) exploitation of deposits. The third division cites literature on the problems of beneficiation and dressing of iron ores and on the methods of beneficiation.

The completeness and excellent organization of the vast amount of material make this reference book a valuable addition to bibliographical literature. It is very easy to use. The book is a useful and essential guide for everyone interested in iron ores; it is especially important to geologists, mining engineers, beneficiators, economists, workers in planning organizations, soviets of people's economy, etc. It permits a rapid and easy orientation in the extensive literature without the danger of missing important material, shows what data are available on a given problem and where, and indicates the extent of knowledge of a given problem, region or deposit.

The bibliography ought to become a handbook for all workers in the iron industry. The Academy of Sciences Press, which published this book, accomplished a great and important task and eased the labors of many workers in our science and in industry. It would be highly desirable to publish a similar guide for the ores of non-ferrous and rare metals.

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THE SECOND PETROGRAPHICAL CONFERENCE

An All-Union Petrographic Conference devoted to the discussion of such vital petrographic problems as the regularities in the development of magmatic and metamorphic processes in the earth's crust and their significance in the distribution of ore deposits will take place in Tashkent in May, 1958.

Attention of the participants will be drawn to the following topics: magmatism and metallogeny of Central Asia, alkalic rocks and associated ores, physicochemical analysis of magmatic and postmagmatic processes, geochemistry of magmatic and metamorphic rocks and of post-magmatic alteration, geologic patterns in the development of magmatism and endogenic mineralization, and the new methods of study of magmatic and metamorphic rocks.